GEOLOGICAL SURVEY CIRCULAR 157

ANNOTATED BIBLIOGRAPHY AND INDEX MAP OF SULFUR AND PYRITES DEPOSITS IN THE UNITED STATES AND ALASKA

(Including references to July 1, 1951)

By Gilbert H. Espenshade and Carl H. Broedel

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GEOLOGICAL SURVEY
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CONTENTS

ILLUSTRATION

INTRODUCTION

THE SULFUR INDUSTRY

Since the end of World War II, the pattern of sulfur production and consumption in the United States and abroad has changed markedly from the pattern that existed before the war. Although production of sulfur in the United States in 1950 was more than double the average annual production for the 1935-39 period, consumption had increased at such a rate that current domestic and foreign demand for U. S. sulfur exceeds the productive capacity of the industry. Production of sulfur (including brimstone, pyrites, and all other forms) in the 1935-39 period and in 1950 are compared in the table below[1].

	1935-39 average production, long tons sulfur	1950 production, long tons sulfur
World, excluding the Communist countries	7,750,000	10,725,000
United States	2,569,000	5,966,000

The important feature of the present situation is that the United States is now contributing a much larger share of the world's sulfur than formerly--over half of the world production in 1950 as compared with about a third of the world total in the 1935-39 period.

[1]Data taken from Carrington (1951); see the annotated bibliography, sulfur and pyrite general reference 1.

Furthermore, the increase in United States sulfur production (about 3,400,000 tons) has been larger than the increase for the world as a whole (about 3,000,000 tons); in other words, sulfur production in the rest of the world was about 400,000 tons less in 1950 than in the pre-war period, owing mainly to decreased production in Europe and Japan. The quantity of sulfur exported from the United States is now more than double the amount exported in the pre-World War II period, amounting to 1,460,967 tons in 1949 as compared to an average of 583,000 tons in the years 1935 to 1939.

The present situation in the sulfur industry has naturally aroused concern about sulfur supplies in the period of defense preparation of the next few years, and about the resources available over a long period of years. To meet the current demand, the sulfur industry has undertaken measures to increase production, mainly by enlarging the capacity of some existing native sulfur mines in the United States and by opening new mines, by greater recovery of by-product sulfur (in the United States mostly from sour natural gas and petroleum refinery gas), and by increasing production of foreign sulfur and pyrites sources (principally in Europe, Canada, and Mexico). It is likely that within a few years the productive capacity will be expanded to the point where the demand for sulfur is satisfied.

The problem of sulfur resources will, of course, be intensified as production is expanded, and this problem is of particular concern to the United States because the large brimstone deposits of the Gulf Coast salt domes are being depleted at a rate about double that of the years preceding World War II. In 1950 the salt-dome deposits supplied about 87 percent of the sulfur produced in the United States, and nearly half of the sulfur produced in the world. Other forms of sulfur--pyrites and other sulfur-bearing ores, hydrogen sulfide in petroleum and natural gas, and anhydrite and gypsum--occur in great abundance in the United States and the rest of the world, but native sulfur has been preferred by many consumers because it has been cheap and plentiful. However, it can be expected that these other sources of sulfur will be utilized to a greater degree in the future as the supply of native sulfur from the salt-dome deposits gradually declines.

EXPLANATION OF ANNOTATED BIBLIOGRAPHY AND INDEX MAP

Considerable literature about the short-term aspects and the long-term aspects of sulfur supplies has appeared in the technical press since mid-1950, covering such subjects as reserves, byproduct recovery, conservation of sulfur and substitutions for sulfur in industrial processes, and trends of future consumption. During this period, the U. S. Geological Survey has received numerous inquiries about sulfur deposits and resources from industrial concerns and government agencies. Many of the inquiries sought information to aid in the exploration of sulfur and pyrites deposits. Because of the very active interest in these deposits, it was thought that some sort of handbook on domestic sulfur and pyrites deposits would be of interest and aid to industry, government, and the general public. A comprehensive treatise on the subject could not be undertaken, because the subject was large and involved and time was short. As an alternate form of guide, this annotated bibliography on domestic sulfur and pyrites deposits and an index map to these deposits were prepared.

Deposits included in the bibliography and index map are native sulfur deposits, pyrites deposits (including pyrite, marcasite, or pyrrhotite deposits, that commonly contain some copper and zinc sulfides), metalliferous deposits (including copper, zinc, lead, iron, gold, molybdenum, etc. deposits) containing significant amounts of iron sulfides, and coal mines that have produced pyrites. The iron sulfide minerals are so common and abundant in all types of metalliferous deposits, that it was often a difficult matter to decide whether a certain metalliferous deposit or district should be included or not. The problem was also complicated by the fact that the geologic literature contains surprisingly little quantitative information on the pyrite content of metalliferous deposits; the usual form of statement is that "pyrite is common" or "pyrite is the most abundant sulfide," and little information is given about the reserves of recoverable pyrite. An effort has been made to include all domestic deposits with significant amounts of iron sulfides, and to exclude those deposits having but minor amounts. Nevertheless, it is likely that readers more familiar with certain deposits will disagree with some of the selections that have been made.

The bibliography is primarily a list of publications describing sulfur- and pyrites-bearing deposits or districts, but a few of the more important papers treating general subjects about the sulfur industry are included. The literature on sulfide ore deposits and Gulf Coast salt domes is so voluminous that it was necessary to limit the reference list to those publications giving information on the occurrence of sulfur and iron sulfides. Older publications that have been superseded by more recent papers have usually been omitted from the list.

The index map shows the locations of sulfur and pyrite deposits in the United States and Alaska, and also indicates the type of deposit, and whether or not it has been productive. Deposits of pyrites are distinguished according to the following classes:

1. Pyrite and marcasite deposits, some containing other recoverable metals.
2. Pyrrhotite deposits, some containing other recoverable metals.
3. Various metalliferous deposits (mostly copper, zinc, lead, iron, gold, and molybdenum) that contain pyrites.
4. Coal mines or districts that have produced pyrites.

A considerable number of pyrite mines and coal mines that produced pyrites prior to and during World War I stopped production shortly after that war because of the wider use of brimstone for sulfuric acid manufacture. For that reason, mines whose pyrite production ceased prior to Jan. 1, 1925 are distinguished on the map from those mines that have produced pyrites between that date and Dec. 31, 1950.

KEY TO ARRANGEMENT OF BIBLIOGRAPHY

References are arranged according to the following classification:

Sulfur and pyrites - general

Sulfur - general

Sulfur deposits in the different states and Alaska

Pyrites - general

Pyrites deposits in the different states and Alaska

An alphabetical list of deposits is given under each state, before the list of references for that state, and the references pertaining to each deposit are shown by numbers listed after the name of the deposit. Numbers without prefix refer to references listed under that state; numbers with the prefix SP refer to references under sulfur and pyrites (general), S refers to sulfur references (general), and P refers to pyrites references (general). References listed under other states are indicated by that state's abbreviation, as Pa 5, or Pennsylvania reference 5.

ANNOTATED BIBLIOGRAPHY

SULFUR AND PYRITES--GENERAL

1. Carrington, J. C., 1951, Current developments in the sulphur situation: Am. Inst. Min. Met. Eng. Trans., paper presented at meeting of Industrial Minerals Division, Sept. 14.

The radical change in the supply and demand for sulfur (including brimstone, pyrites, and all other forms) since 1935 is reviewed. New sulfur mining and recovery projects in the United States and the rest of the world (exclusive of Communist countries) are described; these will have new production of about 3,000,000 tons of sulfur by the end of 1953. Statistics for production of sulfur during 1935-39 and 1950, and estimated new production are given in some detail; this information is summarized as follows:

	1935-39 Av. prod. (long tons)	1950 production (long tons)	Estimated new production (long tons)
United States	2,569,000	5,966,000	1,541,500
Rest of world (excluding Communist countries)	5,181,000	4,759,000	1,464,000

2. Haynes, William, 1942, The Stone that Burns: D. Van Nostrand Co., Inc., New York, 345 pp.

A well documented historical account of the development of the Gulf Coast sulfur industry. The difficulties leading to the successful development of the Frasch process of recovering molten sulfur by superheated water through wells at Sulphur mine, Louisiana, are fully detailed. Exploration and development of other sulfur-bearing salt domes are similarly described. The struggle between the American and Sicilian sulfur industries is discussed at length. The concluding chapter discusses the current and future status of sulfur production and consumption, with particular attention to byproduct sources. Statistical data on sulfur, pyrite, and sulfuric acid are given in 22 tables.

3. Josephson, G. W., Ralston, O. C., and Smith, W. C., 1947, Sulfur (including pyrite and byproduct sulfur compounds), in Mineral position of the United States, by the staffs of the Bureau of Mines and Geological Survey: Hearings before a subcommittee of the committee on Public Lands, U. S. Senate, 80th Congress, 1st sess., pp. 292-296.

Summarizes uses and sources of sulfur and pyrites. Trends in production, consumption, and price of sulfur and pyrites during period 1910-44 are shown in graphs. Estimated domestic reserves of sulfur in deposits of native sulfur and pyrite as of Jan. 1, 1944 are tabulated by regions and districts. Native sulfur reserves, mainly in the Gulf Coast region, are estimated at 60,000,000 long tons available under 1944 conditions, plus 22,200,000 long tons available under future conditions. Sulfur contained in pyrite deposits is estimated at 26,000,000 long tons available under conditions of 1944, plus 50,000,000 long tons available under future conditions. In addition, very large amounts of sulfur are available as potential byproducts from copper, lead, and zinc deposits, coal, industrial and refinery gases, and gypsum and anhydrite. The locations of the principal native sulfur and pyrite deposits in the United States and Alaska are shown on a small map.

4. Lundy, W. T., 1949, Sulphur and pyrites, in Industrial Minerals and Rocks: Am. Inst. Min. Met. Eng., 2d edition, pp. 989-1017.

Discusses the chemical properties of sulfur, the geology and mining operations of the salt-dome sulfur deposits, the sulfur deposits of Sicily and other parts of the world, and the various theories on the origin of native sulfur deposits. Pyrite deposits in the United States, Cyprus, Spain, Norway, Sweden, and Finland are described briefly, and other pyrite-producing countries are mentioned. Marketing, uses, specifications, political and commercial control, and production and consumption are discussed. The bibliography lists 93 references.

5. U. S. Geological Survey, 1882-1923, (annual publication), Pyrites and sulfur, in Mineral Resources of the United States.
   U. S. Bureau of Mines, 1924-1932 (annual publication), Pyrites and sulfur, in Mineral Resources of the United States.
   U. S. Bureau of Mines, 1932 to present, (annual publication), Pyrites and sulfur, in Minerals Yearbook.

Gives statistics of annual production and consumption of sulfur and pyrites in United States and foreign countries, exports and imports, and production of sulfuric acid. Current industrial developments are noted.

6. Schrader, F. C., 1917, Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, 412 pp.

All known occurrences of useful minerals, including pyrites and sulfur, are listed by states.

7. Industrial and Engineering Chemistry, 1950, Sulfur symposium, vol. 42, pp. 2186-2302.

Contains a group of 22 reports on various aspects of the sulfur industry. Topics include reserves, extraction processes at salt dome deposits, H_2S in sour natural gases in Wyoming and west Texas, recovery of H_2S, SO_2, and S from smelter and other industrial gases, sulfur metabolism of plants, etc.

8. Swager, W. L., and Sullivan, J. D., 1951, Sulphur: Mining Engineering, vol. 3., pp. 403-409.

The history of past and current sulfur sources and use patterns is reviewed. An estimate of domestic consumption in 1960 by major industries is shown by graphs and tables; 1960 total may be over

8,000,000 long tons of sulfur as compared to nearly 5,000,000 tons for 1950. Discusses potential sources of byproduct sulfur (exclusive of native sulfur and anhydrite), and estimates that about 3,000,000 additional tons of sulfur could be recovered annually in the United States from metal smelters, natural and industrial gases, and pyrites from metalliferous deposits and coal.

9. Wells, A. E., and Fogg, D. E., 1920, The manufacture of sulphuric acid in the United States: U. S. Bur. Mines Bull. 184, 216 pp.

This bulletin gives the results of the Government survey of sulfur resources and the sulfuric acid industry made during the acid shortage of World War I. Topics discussed are history of the industry (including a list of U. S. acid plants on Jan. 1, 1919), all types of raw materials, and details of equipment and methods used in manufacture. A study of resources of coal pyrites was an important part of the survey; it was estimated that 1,500,000 tons of pyrites containing 40 percent sulfur could be recovered annually from coal mines in eleven eastern states.

SULFUR

General

1. Anonymous, 1930, Oil and sulphur development in the Texas and Louisiana Gulf Coast salt dome region: Texas Gulf Coast Oil Scouts Assoc. and South Louisiana Oil Scouts Assoc., Bull. 1, 128 pp.

The history of oil and sulfur development and oil production is summarized, and data tabulated for individual domes. The geology of the Gulf Coast region is discussed in 22 pages. The sulfur industry is described in 6 pages. An index map showing location of the domes is included. Other subjects treated are methods of geophysical exploration, special articles on 6 domes (none of which are sulfur producers), pipe lines, refineries, and well surveying.

2. Barton, D. C., 1928, The economic importance of salt domes, in Contributions to geology, 1928: Texas Univ. Bull. 2801, 53 pp.

Describes the geologic features of salt domes of Texas and Louisiana, Mexico, northern Germany, and Rumania, and discusses the occurrences of petroleum, sulfur, potash, and common salt in these deposits. Estimates that sulfur reserves of Texas-Louisiana salt domes amount to 140,000,000 tons, plus or minus 30 percent, under current conditions with an additional 40,000,000 tons, plus or minus 30 percent, ultimately available. Reserves of the other materials are also discussed.

3. Goldman, M. I., 1926, Petrography of salt dome cap rock, in Geology of salt-dome oil fields: Am. Assoc. Petroleum Geologists, pp. 50-86.

Describes the petrography of 800 ft of core of gypsum-anhydrite cap rock from the Union Sulphur Co. mine, and discusses the probable origin of the gypsum-anhydrite, the overlying calcite rock, and the sulfur. Concludes that the anhydrite is probably of sedimentary origin because of the banded character of breccia fragments of fine-grained anhydrite. Calcite and sulfur were probably formed from anhydrite through reduction by hydrocarbons from adjacent beds.

4. Goldman, M. I., 1933, Origin of the anhydrite cap rock of American salt domes: U. S. Geol. Survey Prof. Paper 175-D, pp. 83-114.

Author concludes from petrographic studies and field relations that "the anhydrite cap rock of salt domes originated by the residual accumulation and consolidation, on top of a salt stock, of sedimentary anhydrite freed from the salt by solution of the top of the stock." His earlier view was that the anhydrite cap represented an original bed of anhydrite overlying the salt that had been pushed up by the dome. The problem of native sulfur is not treated.

5. Hanna, M. A., 1934, Geology of the Gulf Coast salt domes, in Problems of petroleum geology: Am. Assoc. Petroleum Geologists, pp. 629-678.

A general paper on the geologic features of the salt domes, of the Gulf Coast, Isthmus of Tehuantepec, and Utah-Colorado provinces. Index maps of the salt domes and salt anticlines of these three provinces are included. Mineralogy of the salt, anhydrite, gypsum, and limestone parts of the domes are described. The origin of the structures is discussed as a cycle progressing from the start of flowage of sedimentary salt beds, through development of domal structure and piercement of the overlying beds, with final development of the cap rock by accumulation of insoluble residues. Types of petroleum reservoirs are described.

6. Ridgway, R. H., 1930, Sulphur: U. S. Bur. Mines Inf. Circ. 6329, 55 pp.

General information on sulfur: world sources and reserves, descriptions of major deposits, production, uses, consumption, market statistics, and bibliography. Brief descriptions of salt dome deposits and mining operations along Gulf Coast of Texas and Louisiana. List of sulfuric acid plants in United States.

7. Smith, P. S., 1919, Sulphur and pyrite: U. S. Geol. Survey Mineral Resources U. S., 1916, pt. 2, pp. 405-418.

Summary of information available in 1916 on domestic sulfur deposits, with references to literature.

Deposits in different states and Alaska

California

Auschwitz mine, Lake County - 2, 4
Coso Range deposits, Inyo County - 14
Coyote Mountain deposits, Imperial County - 13
Crater (Last Chance Range) mine, Inyo County - 9, 11, 15, 16, 17
Elgin mine, Colusa County - 6, 12
Full Moon deposit, Imperial County - 13
The Geysers, Sonoma County - 1, 18
Leviathan mine, Alpine County - 7, 17
Sulphur Bank mine, Lake County - 2, 4, 5, 6, 8, 12, 17; S 7
Supan deposits, Shasta County - 3; S 7

1. Allen, E. T., and Day, A. L., 1927, Steam wells and other thermal activity at "The Geysers," California: Carnegie Inst. Washington Pub. 378, 106 pp.

Describes the hot springs area known as "The Geysers," Sonoma County. Data given on temperatures, composition of water and gases, nature of salts (mostly sulfates) and sediments (containing some sulfur and black iron sulfide). Steam wells have been drilled here. Conclude that heat, steam, and gases are of a magmatic origin. A small sulfur deposit was formerly mined at the Sulphur Banks fumarole field, 1 mile from "The Geysers."

2. Anderson, C. A., 1936, Volcanic history of the Clear Lake area, California: Geol. Soc. America Bull., vol. 47, pp. 629-664.

Describes the geology of the area surrounding the southern half of Clear Lake. A series of volcanics that are basaltic to rhyolitic in composition and late Pliocene(?) to recent in age rest upon the Franciscan, Chico, and Martinez. Individual flows and their petrography are described; chemical analyses are included. The Sulphur Bank deposit is briefly described.

3. Averill, C. V., 1939, Mineral resources of Shasta County: California Jour. Mines and Geology, vol. 35, p. 173.

A brief note on the occurrence of native sulfur and H_2S with hot springs, steam vents, and fumaroles at the Supan Sulphur works in Lassen Volcanic National Park, Shasta County.

4. Averill, C. V., 1947, Mines and mineral resources of Lake County, Calif.: California Jour. Mines and Geology, vol. 43, pp. 15-40.

The sulfur-bearing deposits described are the Sulphur Bank mine and Auschwitz property. Four pages are devoted to the Sulphur Bank deposit and the quicksilver mining operations there (see also Everhart). At the Auschwitz property (SW$\frac{1}{4}$ sec. 33, T. 13 N., R. 8 W., Mt. Diablo meridian) sulfur occurs in white decomposed volcanic rock; abandoned workings: 50-foot shaft, 100-foot adit.

5. Becker, G. F., 1888, Geology of the quicksilver deposits of the Pacific slope: U. S. Geol. Survey Mon. 13, pp., 253-257.

Description of geology and occurrence of sulfur at Sulphur Bank, Calif. Sulfur occurred near surface in silicified basalts; cinnabar was found at depth.

6. Bradley, W. W., 1918, Quicksilver resources of California: California Min. Bur. Bull. 78, 389 pp.

Pyrite is a common constituent of the cinnabar ores, and native sulfur is present in some deposits, particularly at the Elgin mine, Colusa County, and the Sulphur Bank mine, Lake County.

7. Bradley, W. W., 1935, Recent nonmetallic mineral development in California: Mining and Metallurgy, vol. 16, pp. 181-184.

In 1934, sulfur was produced from Crater group of claims, Inyo County, and from Leviathan mine, Alpine County. It is estimated that 1,000,000 tons of ore containing 40 percent sulfur has been developed at Leviathan mine. Sulfur has also been mined in Colusa and Kern Counties since 1923.

8. Everhart, D. L., 1946, Quicksilver deposits at the Sulphur Bank mine, Lake County: California Jour. Mines and Geology, vol. 42, pp. 125-153.

The Sulphur Bank deposit was first mined for sulfur from 1865 to 1868, but since then has been worked for quicksilver. Sulfur production amounted to 2 million pounds; quicksilver production to the end of 1944 was 126,285 flasks. Hydrothermal alteration, hot springs, and small fumaroles are widespread along two fault zones and thin intersections. Country rocks are sandstone, shale, etc. of the Franciscan group, Recent landslide and lacustrine deposits, and a Recent andesite flow. At Sulphur Bank the andesite flow is covered with 25 ft of powdery, opaline silica containing sulfur and gypsum. Major hydrothermal minerals are opal, clay, carbonates, quartz, pyrite, cinnabar, stibnite, various sulfates, and sulfur.

9. Lynton, E. D., 1938, Sulphur deposits of Inyo County, Calif.: California Jour. Mines and Geology, vol. 34, pp. 563-590.

Deposits are on west slope of Last Chance Range, Inyo County. Sulfur occurs with gypsum in fault zones in limestones and volcanics, in two groups of deposits about 1$\frac{1}{2}$ miles apart (Crater group and Black Sulphur, Yellow Sulphur, and Sulphur group of claims). Over 30,000 tons of ore containing 75 to 80 percent S have been shipped to chemical plants in Los Angeles. Estimates reserves of proved ore at 253,000 tons averaging 40.3 percent Sulphur, probable total reserves of 2,500,000 tons.

10. Murdock, Joseph, and Webb, R. W., 1948, Minerals of California: California Div. Mines Bull. 136, pp. 289-290.

Gives a comprehensive list of sulfur occurrences in California and cites literature references. Sulfur deposits occur in following counties: Alpine, colusa, Imperial, Inyo, Kern, Lake, Mariposa, Mono, Monterey, San Bernardino, Santa Barbara, Shasta, Siskiyou, Sonoma, Ventura, and Yolo.

11. Norman, L. A., Jr., and Stewart, R. M., 1951, Mines and mineral resources of Inyo County: California Jour. Mines and Geology, vol. 47, pp. 112-113.

Gives brief summary of geology of sulfur deposits in Last Chance Range and current developments at the Crater Group mine. Refinery at this mine was destroyed by explosion in 1941; total production of mine-run and refined sulfur is estimated at 12,000 tons. Material containing 45 percent sulfur is being shipped intermittently.

12. Ransome, A. L., and Kellogg, J. L., 1939, Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, pp. 353-486.

Includes brief accounts of Elgin mine, Colusa County, and Sulphur Bank mine, Lake County, which have considerable native sulfur associated with the deposits.

13. Tucker, W. B., 1926, Imperial County, in Report 22 of the State Mineralogist: California Min. Bur., vol. 22, pp. 284-285.

At the Coyote Mountain deposit, sulfur occurs along a fault fissure in fractures and seams in granite, schist, and limestone. Deposit has an outcrop length of about 100 ft, and has been developed by an open cut and short tunnel. At the Full Moon deposit, sulfur is in seams and fractures in tufa in superficial deposits, 10 to 15 ft thick; considerable development has been done here by shafts, open cuts, and tunnels.

14. Tucker, W. B., 1926, Inyo County, in Report 22 of the State Mineralogist: California Min. Bur., vol. 22, p. 523.

At the Associated Sulphur mines in the Coso Range, sulfur occurs with alum in small solfataric deposits in lava. Sulfur deposits in the Last Chance Range are mentioned very briefly.

15. Tucker, W. B., and Sampson, R. J., 1938, Mineral resources of Inyo County: California Jour. Mines and Geology, vol. 34, pp. 487-492.

Sulfur deposits in the Last Chance Range were discovered in 1917, and actively worked since 1929. Principal mining operations are at Crater Group of claims, currently producing 100 tons of ore daily which is refined at mine to yield product running 99.8 percent sulfur. Also describes development and operations at Fraction and Southwest group, and Gulch group of claims.

16. Vernon, J. W., 1950, Chapter on sulfur, in Mineral commodities of California: California Div. Mines Bull. 156, pp. 273-275.

State's total production of native sulfur is over 52,000 long tons, most of which came from Inyo County mines; commercial production has also come in recent years from Imperial and Alpine Counties. Other counties in which native sulfur has been noted are Colusa, Kern, Lake, Sonoma, Tehama, and Ventura. Largest known deposits are in Last Chance Range, Inyo County.

17. Vernon, J. W., 1951, California sources of sulfur and sulfuric acid, in Minerals useful to California agriculture: California Div. Mines Bull. 155, pp. 129-130.

Principal native sulfur mines in recent years have been those of the Last Chance Range, Inyo County; other deposits of native sulfur are the Leviathan mine, Alpine County, Sulphur Banks deposit, Lake County, and sulfur-bearing gypsum deposits in Imperial County. Chief pyrite producing mine is the Hornet mine, Shasta County. Pyrite was mined in Alameda County from 1891 to 1934. Other pyrite deposits are known in Siskiyou, Mendocino, and Santa Clara Counties; pyrrhotite deposits occur in Orange, San Diego, and Trinity Counties.

18. Vonsen, Magnus, 1947, Minerals at "The Geysers," Sonoma County, Calif.: California Jour. Mines and Geology, vol. 42, pp., 287-293.

A description of the minerals found in this area of hot springs and fummaroles. Sulfur is the most common mineral. Twelve different sulfate minerals have been identified. Pyrite, cinnabar, and opal are present. The high ammonia content of the thermal waters is unusual.

Colorado

Grand Junction deposit, Mesa County - 2, 4; S 7
Gunnison Fork mine, Delta County - 1, 2, 4
Middle Fork deposit, Mineral County - 2, 3, 4; S 7
Trout Creek deposit, Mineral County - 2, 3, 4; S 7

1. Dings, G., 1949, The Gunnison Forks sulfur deposit, Delta County, Colo.: Colorado Sci. Soc. Proc., vol. 15, pp. 237-256.

Thin lenticular shale and sandstone beds in the Dakota formation contain pyrite nodules and local concentrations of native sulfur and alum minerals. H_2S-bearing gas seeps in vicinity have probably been source of sulfur. Material mined and sold as soil conditioner; most of mining since 1945. Some sulfur analyses are listed. Concludes that future of deposit depends largely upon use of material as soil conditioner rather than as source of native sulfur.

2. Larrabee, D. M., and others, 1947, Map showing construction materials and nonmetallic mineral resources of Colorado: U. S. Geol. Survey Missouri Basin Studies Prelim. Map no. 10, scale 1:500,000.

States that sulfur has been reported in Delta, Gunnison, Mesa, Mineral, and Teller Counties; shows location of deposits in Delta, Mesa, and Mineral Counties.

3. Larsen, E. S., and Hunter, J. F., 1913, Two sulphur deposits in Mineral County, Colo.: U. S. Geol. Survey Bull. 530-0, pp. 363-369.

Description of Trout Creek and Middle Fork sulfur deposits. Sulfur occurs with opal, chalcedony, and pyrite in bleached and altered andesite. Gypsum, alunite, and some barite are present in altered rock free of sulfur. Deposits probably of hot-spring origin. Some mining at Trout Creek deposit.

4. Vanderwilt, J. W., and others, 1947, Sulfur, in Mineral resources of Colorado: Colorado Min. Res. Board [Bull.], pp. 265-266.

Lists known sulfur deposits in Colorado as follows: Black Canyon of Gunnison River, Delta County; gossan of Vulcan pyritic deposit, Gunnison

County; near Grand Junction, Mesa County; south of Creede, Mineral County; 20 miles east of Dolores, Montezuma County.

Florida

Floral City, Citrus County - 1

1. Sellards, E. H., 1908, Annual report of state geologist: Florida Geol. Survey, 1st Ann. Rept., 1907-8, pp. 44-45.

A large mass of native sulfur, estimated to weigh about 2 tons, was dredged from phosphate pit near Floral City. The sulfur occurred either on Oligocene limestone or in it. Sulfur may have formed from H_2S gas in underground water.

Idaho

Soda Springs deposit, Caribou County - 1, 2, 3; S 7

1. Mansfield, G. R., 1927, Geography, geology, and mineral resources of part of southwestern Idaho: U. S. Geol. Survey Prof. Paper 152, pp. 341-342.

Describes sulfur springs and deposits in T. 9 S., R. 42 E. (described by Richards and Bridges, U. S. G. S. Bull. 470), and in T. 10 S., R. 43 E. southeast of Soda Springs. Sulfur occurs with gypsum as incrustations on and impregnations in limestone, and as matrix of fault breccia. Deposits worked prior to 1912; new plant installed in 1918, but never operated. Judges that sulfur was deposited from H_2S near the surface, and that deposits are shallow. Future outlook not bright.

2. Richards, R. W., and Bridges, J. H., 1911, Sulphur deposits near Soda Springs, Idaho: U. S. Geol. Survey Bull. 470-J, pp. 499-503.

Sulfur and small amounts of gypsum occur as cement of fault breccia composed of fragments of tuff, limestone, and quartzite. Numerous springs in vicinity issue H_2S and CO_2 gases, probably of volcanic origin; spring waters are cloudy due to presence of free sulfur. Considerable sulfur produced in 1901 and 1902, plant dismantled in 1910. Authors doubt that deposits can be worked in competition with higher-grade deposits of Wyoming and Utah.

3. Staley, W. W., and Prater, L. S., 1945, Sulphur in Idaho: Idaho Bur. Mines and Geology Mineral Res. Rept. 2, 7 pp.

Brief notes on sulfur deposits near Soda Springs, Caribou County. Deposits occur in fault zone; sulfur associated with gypsum, and cements fault breccia. Three deposits with total exposed area of about 4 1/3 acres. Composite grab sample of 35 ft of pit face carried 13.1 percent sulfur.

Louisiana

Bay St. Elaine dome, Terrebonne Parish - 7, 8, 10; SP2; S1
Belle Isle dome, St. Mary Parish - 1, 5, 7, 8, 10, 12; SP2; S1
Dog Lake dome, Terrebonne Parish - 8; S1
Garden Island Bay dome, Plaquemines Parish - 3, 7, 8, 10; S1
Grande Ecaille dome, Plaquemines Parish - 3, 6, 7, 8, 10; SP2; S1
Jefferson Island dome, Iberia Parish - 7, 8, 9, 10, 12; SP2; S1
Lake Pelto dome, Terrebonne Parish - 8; S1
Starks dome, Calcasieu Parish - 8; S1
Sulphur dome, Calcasieu Parish - 2, 4, 7, 8, 10; SP2; S7
Venice dome, Plaquemines Parish - 3

1. Barton, D. C., 1935, Belle Isle salt dome, St. Mary Parish, Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 19, pp. 644-650.

Gives a summary of the geology of the Belle Isle dome from information gathered by drilling and torsion-balance survey. Cap rock covers most of the dome and lies at a depth of 300-500 ft beneath the surface, except for a salt spine that is bare of cap rock and comes to within 100 ft of the surface. The dome was prospected for sulfur in 1916-17 by Capt. Lucas (6 wells), by the Union Sulphur Co. in 1921-25 (10 holes), and by the Freeport Sulphur Co. in 1929-30 (torsion-balance survey and 7 holes).

2. Baurenschmidt, J. A., Jr., 1930, Sulphur dome, Calcasieu Parish, Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 14, pp. 1079-1086.

After sulfur mining by the Union Sulphur Co. ceased in 1924, oil was discovered in the sediments flanking the dome. The dome is shown in plan and section. The cap rock is nearly circular in plan, has an area of 75 acres, and thickness of 1,100 ft.

3. Howe, H. V. W., and McGuirt, J. H., 1936, Reports on the geology of Plaquemines and St. Bernard Parishes; Salt domes of Plaquemines and St. Bernard Parishes; Louisiana Geol. Survey, Geol. Bull. 8, pp. 200-278.

Describes and gives exploration results of following domes: Lake Washington (or Grande Ecaille), Lake Hermitage, Garden Island Bay and Venice. Geology of the domes is described and illustrated by cross sections and maps. The paleontology of the drill cuttings is treated in detail. Freeport Sulphur Co. began exploration for sulfur at Grande Ecaille in April 1932, and began production in December 1933. Over 500,000 tons of sulfur was produced by end of 1935; more than 1,200,000 bbl. of oil had been produced by then also. Twelve holes were drilled on Lake Hermitage dome for sulfur by Texas Gulf Sulphur Co., who relinquished the sulfur rights since 1933.

4. Kelley, P. K., 1926, The Sulphur salt dome, Louisiana, in Geology of salt-dome oil fields: Am. Assoc. Petroleum Geologists, pp. 452-469.

The Gulf Coast sulfur industry began at the Sulphur salt dome of Calcasieu Parish with the development of the Frasch process of extracting molten sulfur through wells by means of superheated water. Geologic features of the deposit are described. Sulfur occurs in the transition zone between "lime" rock and the underlying anhydrite that caps the salt plug. The small area of the dome, about 75 acres, its great thickness of about 1,000 ft of caprock, and the richness of the sulfur deposit are unusual. About 9,000,000 long tons of sulfur have been produced by the Union Sulphur Co.

5. Lucas, A. F., 1917, A review of the exploration at Belle Isle, L.: Am. Inst. Min. Eng. Trans. vol 57, pp. 1034-1049.

Describes exploration of the Belle Isle salt dome, first drilled in 1896. Sulfur-bearing cap rock that occurs in a saddlelike depression on top of dome is discussed.

6. Lundy, W. T., 1934, The development of the Grande Ecaille salt dome: Am. Inst. Min. Met. Trans., vol. 109, pp. 354-369.

Describes the exploration and development of the Grande Ecaille sulfur deposits. The swampy nature of the area caused difficult engineering problems that were solved by special procedures described in report.

7. Moresi, C. K., 1936, Sulphur in Louisiana Dept. Conserv. 12th Bienn. Rept., 1934-35, pp. 475-491.

A review of the sulfur mining industry in Louisiana, which had produced more than 10,000,000 tons of sulfur by the end of 1935. The productive sulfur-bearing salt domes--Sulphur, Jefferson Island, and Grande Ecaille--are described briefly. Notes are given on location and extent of explorations on other prospective sulfur-bearing domes: Napoleonville, Black Bayou, Choctaw, Chacahoula, Garden Island Bay, Lake Hermitage, Belle Isle, and Bay St. Elaine.

8. Moresi, C. K., 1936, Oil and gas fields, Sulphur, and Salt in General Minerals Bulletin: Louisiana Dept. Cons. Geol. Bull. 27, pp. 60-176.

Includes information on location, geology, and exploration of Louisiana salt domes.

9. O'Donnell, Lawrence, 1935, Jefferson Island salt dome, Iberia Parish, Louisiana; Am. Assoc. Petroleum Geologists Bull., vol. 19, pp. 1602-1644.

Describes Jefferson Island salt dome at Lake Peigneur, and the explorations for salt, sulfur, and oil. The dome has an unusual shape, the top of the main part of the salt mass is nearly level (800-950 ft below surface), but in the southeastern third of the dome a conical spine of salt projects to within 100 ft of the surface. Several hundred feet of caprock (lime-rock and anhydrite) overlie the main part of the mass; sulfur occurs here in the transition zone between lime-rock and anhydrite. There is no caprock or sulfur above the salt spine. Nearly 400,000 long tons of sulfur was produced from 1932 to 1934. Over 2 million tons of salt produced from mine in the salt spine between 1923 and 1934. Numerous cross sections of the dome are shown.

10. Shaw, J. A., 1938, Sulphur (in Louisiana): Louisiana Dept. Conserv., 13th Bienn. Rept. for 1936-37, pp. 352-363.

Describes deposits and operations at two sulfur-producing salt domes in the State--Jefferson Island and Grande Ecaille domes. Geological features and exploration of the following other domes are also described: Sulphur, Napoleonville, Black Bayou, Choctaw, Chacahoula, Garden Island Bay, Lake Hermitage, Belle Isle, and Bay St. Elaine domes.

11. Taylor, R. E., 1938, Origin of the cap rock of Louisiana salt domes: Louisiana Geol. Survey Bull. 11, 191 pp.

The various problems of the salt domes are summarized, and the problem of origin of the cap rock is considered in detail based upon extensive mineralogical studies of the salt and cap rock. Similar insoluble minerals (principally anhydrite, accompanied by quartz, various sulfates, sulfides, and other minerals) occur in the salt and in the cap rock. For this and other reasons, Taylor concludes that the cap rock has formed by accumulation of the insoluble minerals normally present in the salt. Sulfur, calcite, and gypsum were formed by alteration of anhydrite. The most probable agents causing the reductions of sulfates to sulfur are hydrogen sulfide, hydrocarbons, and sulfate-reducing bacteria. The mineralogy of three cap rock drill cores is described. Insoluble residues and thin sections are illustrated in 26 plates. This informative paper also contains a comprehensive bibliography

12. Vaughan, F. E., 1926, The Five Islands, Louisiana, in Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, pp. 356-395.

The Five Islands are five rounded hills, about 100 ft in elevation, that occur along a line on the Louisiana Gulf coast. The hills are underlain by salt domes, which are named in order from the northwest: Jefferson Island, Avery Island, Weeks Island, Cote Blanch, and Belle Isle. The geology of each dome is described. Very little cap rock occurs on the Jefferson Island, Avery Island and Weeks Island domes; salt is mined from each of these domes. Considerable cap rock containing some sulfur occurs in the Belle Isle dome; this dome has been explored for sulfur.

Nevada

Cuprite (Deep Gulch) mine, Esmeralda County - 5, 6, 7; S7

Humboldt (Rabbit Hole) mine, Humboldt County - 1, 2, 4, 6; S7

Silver Peak (Blair) mine, Esmeralda County - 3, 5, 8; S7

Tognoni Springs deposit, Esmeralda or Nye County - 7; S7

1. Adams, G. I., 1904, The Rabbit Hole sulphur mines near Humboldt House, Nev.: U. S. Geol. Survey Bull. 225, pp. 497-500.

Sulfur occurs with alunite, gypsum, and a little cinnabar in altered siliceous volcanics. Deposits being mined in 1904, and sulfur extracted from ore by superheated steam.

2. Crowley, A. J., 1924, A novel sulphur enterprise in Nevada: Eng. and Min. Jour. -Press, vol. 118, pp. 774-776.

Humboldt Sulphur Co. mine is in Sulphur, Nev. on the northwest flank of Kamma Mountains, and has been worked intermittently since the 1870's. Describes mining and milling operations. States that "development work since 1917 have [has] led to the conclusion that the major ore bodies are as yet untouched." Sulfur recovery has been poor, less than 50 percent; there are probably 150,000 tons of material on the dump which carry 13 to 27 percent Sulfur.

3. Duncan, L., 1921, Recovery of potash alum and sulphur at Tonopah: Chem. Met. Eng., vol. 24, pp. 529-530.

The alum-sulfur deposit, 35 miles west of Tonopah, Nev., (described by Spurr), is being worked by Western Chemicals, Inc. More than 100,000 tons of ore has been blocked out, and probable tonnage is more than 1,000,000 tons. Average ore contains about 20 percent potash alum, 15 percent S, 58.8 percent SiO_2, 2.1 percent $CaSO_4$, and 1.2 percent $CaCO_3$. Alum is recovered by solution in hot water, and sulfur by flotation. Capacity of plant is 10 tons of alum and 10 tons of 85 percent sulfur concentrates daily.

4. Hazen, H. L., 1929, Recovering sulphur from a Nevada surface deposit: Eng. and Min. Jour., vol. 127, pp. 830-831.

Description of methods used by Humboldt Sulphur Co. to extract sulfur from ore deposits at Sulphur, Nev.

5. Hewett, D. F., and others, 1936, Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, pp. 147-149.

Brief notes on sulfur deposits near Cuprite, Nev. (apparently mined out) and at Sulphurdale, Utah (has produced about 40,000 tons of sulfur, and seems to have fairly large reserves). The alum deposit 12 miles south of Blair Junction, Esmeralda County, Nev. contains both sulfur and alum in white powdery rock altered from rhyolite. An attempt was made to work this deposit in 1921, but it was later abandoned.

6. Lincoln, F. C., 1923, Mining districts and mineral resources of Nevada, pp. 63-64, 103-104, Reno, Nevada Newsletter Pub. Co.

Information on the sulfur deposits and mining operations in the Cuprite district, Esmeralda County, and the Sulphur or Rabbit Hole district, Humboldt County is summarized.

7. Ransome, F. L., 1909, Geology and ore deposits of Goldfield, Nev.: U. S. Geol. Survey Prof. Paper 66, pp. 109-110.

Brief notes on occurrences of sulfur about 1 mile east of Tognoni Springs (5 miles east of Goldfield), on Blue Bull claim, and near Cuprite (12 miles south of Goldfield). At Tognoni Springs deposit, sulfur is in andesite altered to powdery siliceous material. Near Cuprite, sulfur occurs in white powdery silica and alunite.

8. Spurr, J. E., 1904, Alum deposit near Silver Peak, Esmeralda County, Nev.:, U. S. Geol. Survey Bull. 225, pp. 501-502.

Sulfur occurs with alum and gypsum as stringers and veins in decomposed rhyolite; bright-red stains are probably cinnabar. Two mineralized areas, one about 200 ft in diameter, the other about 30 ft.

New Mexico

Jemez Sulphur Springs, Sandoval County - 1, 2

1. Northrop, S. A., 1944, Minerals of New Mexico: Univ. New Mexico Press, pp. 295-297.

Lists following occurrences of sulfur in the State: Near Artesia, Eddy County; White Oaks district, Lincoln County; Otero County; near Tres Piedras, Rio Arriba County; Jemez Sulphur Springs, Sandoval County.

2. Smith, P. S., 1921, Sulphur and pyrites: U. S. Geol. Survey, Mineral Resources U. S., 1918, pt. 2, pp. 367-371.

Includes description of two sulfur deposits in Jemez Canyon, Sandoval County, N. Mex., by G. R. Mansfield. San Diego deposit is about 1 acre in extent, occurs in surface mantle and limestone bedrock. Sulphur Springs deposit is about 9 acres in size, occurs in rhyolite. Small amount of ore mined about 1902. Deposits only few feet thick, and probably of no commercial importance.

Oregon

Last Chance mine, Douglas County - 1

1. Oregon Dept. Geol. and Min. Industries, 1940, Oregon metal mines handbook; Bull. 14-C., vol. 1, pp. 131-132.

Information on the Last Chance sulfur mine, Douglas County. Deposits consists of small masses of native sulfur in fault zone in rhyolite. Sulfur exposed over length of about 200 ft; fault zone can be traced for over half a mile. Other deposits reported in the vicinity.

Texas

Big Creek dome, Fort Bend County - SP2; S1
Big Hill dome, Matagorda County - 14; SP2; S1
Boling dome, Wharton County - 15; SP2; S1
Bryan Heights dome, Brazoria County - 9; SP2; S1
Clemens dome, Brazoria County - SP2; S1
Hoskins Mound dome, Brazoria County - 4, 6, 10; SP2; S1
Long Point dome, Fort Bend County - SP2; S1
Moss Bluff dome, Liberty County - S1
Nash dome, Fort Bend and Brazoria Counties - 5; S1
Orchard dome, Fort Bend County - SP2; S1
Palangana dome, Duval County - 3; SP2
Rustler Springs dist., Culberson County - 8, 11, 12, 13; S7
Spindletop dome, Jefferson County - 2, 7; S1, S7

1. Bartlett, Z. W., 1946, Salt and sulphur resources of Texas: Texas Acad. Sci. Proc. and Trans., vol. 29, pp. 186-191.

Brief general statement on sulfur resources of Texas. Out of 70 salt domes discovered in Texas, sulfur has been produced in commercial quantities from only 8 domes. About 46,000,000 tons of sulfur has been produced from Texas deposits.

2. Barton, D. C., and Paxson, R. B., 1926, The Spindletop salt dome and oil field, Jefferson County, Tex., in Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, pp. 478-496.

Oil was discovered in 1901 on the Spindletop dome in a spectacular gusher well; 30 million bbl. were produced in the next 3 yrs., and over 50 million bbl. total production. The dome has a salt core with a circular outline and a diameter of about 1 mile. The salt core is capped by anhydrite and gypsum which are covered with limestone. Sulfur occurs in the limestone and in the overlying sand and clay. Origin of the dome and cap are briefly discussed.

3. Barton, D. C., 1926, The salt domes of south Texas, in Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, pp. 718-771.

The Palangana, Piedras Pintas, and Falfurrias salt domes, and five possible salt domes are discussed. The Palangana dome was discovered in 1916 and drilled for oil by several companies. The Texas Gulf Sulphur Co. drilled 25 holes for sulfur in 1924, and the Union Sulphur Co. drilled 3 holes. A circular ring of low hills around a central basin lies about the Palangana dome. The salt core is nearly circular in outline withaa ldiameter of 11,000 ft. Cap rock consists of clay and shale with sulfur and blocks of limestone; this is underlain by gypsum and anhydrite. The different theories of origins of salt domes are discussed.

4. Barton, D. C., 1936, Calculation of the cap from torsion-balance data, Hoskins Mound salt dome, Brazoria County, Tex.: Am. Inst. Min. Met. Eng. Tech. Pub. 719, 10 pp.

Exploration drilling at Hoskins Mound had only partly outlined the cap rock of the dome. Torsion-balance survey was run in order to determin the approximate position of the edge, depth, and thickness of the cap rock mass. Results from this survey were found by subsequent drilling to approximate actual conditions; this is illustrated in structural sections. Results aided the drilling program of the Freeport Sulphur Co.

5. Barton, D. C., 1944, Gravity anomalies of Nash and Damon Mounds, Fort Bend and Brazoria Counties, Tex.: Am. Inst. Min. Met.Eng. Tech. Pub. 1760, pp. 2-9.

The Nash and Damon salt domes, 5 miles apart, have pierced at least 20,000 ft of sediments. The Nash was the first salt dome to be discovered by geophysical methods; existence of a dome was suspected because of presence of H_2S in water wells here. Depth to top of cap is 620 ft, and to top of salt, 920 ft; a 5-foot topographic mound is present. The gravity anomalies of both mounds are discussed. No mention of sulfur.

6. Culbertson, J. A., Eby, J. B., and Thompson, W. C., 1941, Guide for field trips, American Association of Petroleum Geologists 26th annual meeting: Houston Geol. Soc., 28 pp.

Contains croos-sections and maps of Hoskins Mound, Hockley Dome, and several other salt domes, and oil fields. Freeport Sulfur Co. began operations at Hoskins Mound on March 31, 1923, and had produced 6,085,340 tons of sulfur by Jan. 1, 1941.

7. Eby, J. B., and Halbouty, M. T., 1937, Spindletop oil field, Jefferson County, Tex.: Am. Assoc. Petroleum Geologists Bull., vol. 21, pp. 475-490.

Describes the Spindletop dome, and discusses the occurrence of oil in the formations flanking the dome. The cap rock, with a thickness of 700 ft or more, is indicated in a subsurface contour map and in vertical sections. No mention of sulfur.

8. Evans, Glen L., 1946, The Rustler Springs sulphur deposits as a source of fertilizer: Texas Univ. Bur. Econ. Geology Rept. 1, 13 pp.

Deposits are in outcrop area of Castile formation along west flank of Delaware syncline, Culberson County, Tex. The thick gypsum beds of the Castile formation are covered by mantle of alluvial material and gypsite; sulfur occurs in both bedrock and mantle. Acidic sulfur earth occuring at places in mantle is a mixture of clay, sand, gypsum, sulfur, and sulfuric acid. This acidic sulfur earth has been mined and shipped as a soil conditioner for alkali soils in lower Rio Grande Valley.

9. Kennedy, W., 1926, The Bryan Heights salt dome, Brazoria County, Tex., in Geology of salt-dome oil fields: Am. Assoc. Petroleum Geologists, pp. 678-690.

Sulfur was discovered in the cap rock of the Bryan Heights dome during unsuccessful drilling for oil. After further exploration for sulfur, production was begun in late 1912 by the Freeport Sulphur Co. Geology of the cap rock and the salt plug are described. Cross sections and structure-contour map of the dome.

10. Marx, A. H., 1936, The Hoskins Mound salt dome, Brazoria County, Tex.: Am. Assoc. Petroleum Geologists Bull., vol. 20, pp. 155-178.

Sulfur was discovered in cap rock of Hoskins Mound salt dome during exploration for oil. Freeport Sulphur Co. began mining in 1923 and have produced more than 4,000,000 long tons of sulfur. Geologic features are described, and origin of salt dome, cap rock and sulfur are discussed. Sampling methods and mining operations are described. Cross sections of the dome.

11. Phillips, W. B., 1918, The sulphur deposits in Culberson County, Tex.: Am. Inst. Min. Eng. Trans., vol. 58, pp. 265-283.

The principal deposits are near Maverick Springs and Rustler Springs. Native sulfur occurs in surficial material and gravel, and in dolomite and gypsum; sulfur may have been formed by alteration of bituminous gypsum. States that previous extravagently optimistic views of potentialities of district have been based on very inadequate sampling. Believes that several areas have good possibilities, but systematic exploration is needed.

12. Porch, E. L., Jr., 1917, The Rustler Springs sulphur deposits: Texas Univ. Bull. 1722, 71 pp.

Describes geology and sulfur deposits of the Rustler Springs district, Culberson and Reeves Counties. Numerous sulfur deposits occur in outcrop area of gypsum beds of Castile formation, an oval area about 46 miles long and 22 miles wide. Surface is covered with thin layer of earthy gypsite which contains some sulfur. Most of the sulfur, however, is in underlying brown siliceous material and dark gypsum-bearing earth. Deepest working is shaft, 43 feet deep, on land of Michigan Sulphur and Oil Co., which has good sulfur content at bottom. Sulfur has been found in gypsum at depths of 550 to 600 ft in wells in Pecos County, 90 miles to the southeast. Hydrogen sulfide gas escapes at many places in the areas, and is thought to be source of the sulfur; the H_2S may have formed from reduction of gypsum by hydrocarbons, or from pyrite or organic matter present in underlying beds. Individual mines and deposits are described; most extensive work done in last 2 years. Some analyses of medium- and high-grade ores given.

13. Richardson, G. B., 1905, Native sulphur in El Paso County, Tex.: U. S. Geol. Survey Bull. 260, pp. 589-592.

Deposits are in Rustler Spring area, formerly El Paso County, but now Culberson County. Sulfur occurs with earthy gypsum overlying limestone and gypsum beds; H_2S gas escaping in places. Sulfur and H_2S believed to be derived from gypsum. Two or three carloads of refined sulfur shipped about 1900.

14. Wolf, A. G., 1926, Big Hill salt dome, Matagorda County, Tex., in Geology of salt-dome oil fields: Am. Assoc. Petroleum Geologists, pp. 691-717.

The Big Hill dome was drilled for oil between 1902 and 1904 without much success. Discovery of sulfur during these operations encouraged exploration for sulfur, and in 1919 the Texas Gulf Sulphur Co. began its first sulfur production here. Geology of the deposits, mineralogy of the cap rock, and origin of the dome and the sulfur deposits are discussed. Methods of sampling and sulfur mining are described.

15. Wolf. A. G., 1933, The Boling dome, Tex., in Oklahoma and Texas, Guidebook 6: Internat. Geol. Cong., 16th sess., United States, pp. 86-91.

Sulfur production from the Boling dome was begun in 1929 by the Texas Gulf Sulphur Co. The dome is oval shaped in horizontal section, having diameters of 5 by 3 miles on the 1500-foot contour. The sulfur-bearing area is crescent shaped and covers about 1,200 acres on the south and east slopes of the dome. The total estimated amount of sulfur is more than 40,000,000 tons. Sulfur with considerable amounts of barite, celestite, and pyrite occur in the cap rock. Operating methods are outlined.

Utah

Cove Creek (Sulphurdale) mine, Beaver County - 1, 3, 4; Nev. 5; S7
San Rafael Canyon, Emery County - 1, 2
Sulphur, Iron County - 1

1. Buranek, A. M., and Needham, C. E., 1949, Directory of Utah mineral resources and consumers guide: Dept. Publicity and Industrial Development, Raw Materials Div. Bull. 36, pp. 22-23.

Lists following sulfur deposits and owners:

R. L. Fenton, Parowan, Utah:
Deposits near Green River, 8 miles from Woodside, Emery County.
Deposits at Sulphur, Iron County (near Lund).

Utah Sulphur Corp., Sulphurdale, Utah:
Sulphurdale deposits, Beaver County.

2. Hess, F. L., 1913, A sulphur deposit in the San Rafael Canyon, Utah: U. S. Geol. Survey Bull. 530-0, pp. 347-349.

Sulfur occurs with gypsum and impure limestones in vicinity of springs that issue H_2S gas. Exposed mineralized area is 100 to 150 ft wide and 750 ft long. Several other sulfur deposits in region are mentioned.

3. Lee, W., T., 1908, The Cove Creek sulphur beds, Utah: U. S. Geol. Survey Bull. 315-Q, pp. 485-489.

Deposits are located at Sulphurdale 20 miles north of Beaver. Sulfur occurs in irregular veins and masses, 10-15 ft in diameter in soft rhyolitic tuff. Sulfur has evidently been deposited from H_2S gas of volcanic origin. One deposit has been worked over several acres, but lateral and vertical extent are unknown. Deposits have been mined for about 30 years. Minimum grade ore mined contains 15 percent sulfur.

4. Thompson, R. B., 1937, Utah sulphur industries: Compass, vol. 17, pp. 166-169.

Describes briefly the geology and sulfur mining operations at the Sulphurdale deposit, Beaver County, and nearby Purgatory deposit, Millard County. Deposits have been mined rather extensively since the 1880's. Present flotation plant was built in 1927 by Utah Sulphur Industries and has daily capacity of 134 tons. Concentrates analyze 81.01 percent sulfur and 16.71 percent SiO_2.

Washington

Minnie prospect, Okanogan County - 5
Mt. Adams deposit, Yakima County - 1, 2, 3, 4, 5
White River deposit, King County - 2, 5

1. Fowler, C. S., 1936, The geology of the Mount Adams Country (abstract): Geol. Soc. Oregon Country News Letter, vol. 2, pp. 2-5, Jan. 8.

Resume of lecture on Mount Adams. Sulfur occurs beneath glacial ice within the crater; abundant H_2S issues from vents in the crater. About 70 acres of the crater have been prospected for sulfur, by 16 diamond-drill holes (total length of 2,300 ft) and by test pits. Pores and fissures in the volcanic rocks are filled with sulfur. Alum and gypsum are associated with the sulfur.

2. Glover, Sheldon L., 1936, Nonmetallic mineral resources of Washington: Washington Div. Geology Bull. 33, p. 114.

Brief mention of sulfur occurrences at Mount Adams; Naches Highway, Pierce County; and Sulphur Creek, Snohomish County.

3. Matthews, A. F., and Mitchell, A. W., 1943, Sulfur and pyrites, in Minerals Yearbook for 1941, U. S. Bur. Mines, p. 1360.

Note that the sulfur deposit on Mount Adams, Yakima County, Wash., that was estimated in 1935 to contain 842,000 long tons of material containing 46 percent sulfur, has been explored further by Pacific Sulphur Mines, Inc., and larger amounts of sulfur found.

4. Throssell, W. I., 1940, The massif (Mt. Adams in southwestern Washington): Rocks and Minerals, vol. 15, pp. 14-19.

A popular account and travelogue of Mt. Adams and vicinity. Summarizes results of exploration for sulfur in 1931, 1934, and 1935. It is reported that reserves of 841,571 long tons of 46 percent sulfur ore have been found in an area of 40 acres; sulfur is known to occur on about 200 acres. Alum and gypsum underlie the sulfur.

5. Valentine, G. M., 1949, Inventory of Washington minerals: Washington Div. Mines and Geology Bull. 37, pt. 1, pp. 99-100.

Notes on occurrences of sulfur in Washington and index map of locations. Authenticated occurrences are Mt. Adams, Yakima County; White River, King County; and Minnie prospect, Okanogan County. At Mt. Adams deposits 48,000 tons of 48 percent sulfur ore is said to have been blocked out.

Wyoming

Afton deposit, Lincoln County - SP 5
Cody deposits, Park County - 1, 5; S 7
South Fork Shoshone River deposit, Park County - 1
Sunlight Basin deposits, Park County - 1, 2; S 7
Sweetwater Creek deposits, Park County - 1, 3; S 7
Thermopolis (Brutch) deposit, Hot Springs County - 1, 4, 6; S 7

1. Clabaugh, S. E., and others, 1946, Map showing construction materials and nonmetallic mineral resources of Wyoming: U. S. Geol. Survey Missouri Basin Studies Prelim. Map 9, scale 1:500,000.

Shows locations of five groups of sulfur deposits in Hot Springs and Park Counties. Deposit on south fork of Shoshone River was not found mentioned in other literature.

2. Hewett, D. F., 1913, Sulphur deposits of Sunlight Basin, Wyoming: U. S. Geol. Survey Bull. 530-O, pp. 350-362.

Six sulfur deposits occur in altered and silicified areas in andesite flows and breccias in broad zone of fracturing about 3½ miles long. Sulfur occurs as cement in surface debris, and as incrustations and impregnations in bedrock; surface material has highest sulfur content, the maximum being about 60 percent. Gypsum, alkali alums, ferrous sulfate, and marcasite(?) also present. Sulfur probably deposited from gases containing H_2S and CO_2 that are now issuing from fractures.

3. Hewett, D. F., 1914, Sulphur deposits in Park County, Wyo.: U. S. Geol. Survey Bull. 540-R, pp. 477-480.

Describes sulfur deposits along Sweetwater Creek that are very similar to those in Sunlight Basin, 12 miles to north. Sulfur occurs as cement in altered alluvial and surface debris, and as filling in narrow crevices in andesite bedrock. Hydrogen sulfide issues from the crevices and marcasite(?) is present. Largest mineralized area is about 6 acres; total area in which sulfur has been found does not exceed 20 acres. The upper 2 ft of the largest area are barren of sulfur, but pits about 10 ft deep found sulfur in the underlying debris. Concludes that deposits are rather small, and that little sulfur will be found below water level.

4. Majors, F. H., 1946, Exploration of the Brutch sulfur deposits, Hot Springs County, Wyo.: U. S. Bur. Mines Rept. Inv. 3964, 15 pp.

Deposits are 3½ miles northwest of Thermopolis. Irregular bodies of sulfur with gypsum occur in travertine and limestone. Mines worked prior to 1923; production records not available. Sulfur exposed to depth of about 100 ft in one pit. Exploration by Bureau of Mines in 1944 consisted of rehabilitation of old workings, and digging test pits, shafts, and trenches. Assay data are given, for 219 samples. Results of metallurgical tests summarized.

5. Woodruff, E. C., 1908, Sulphur deposits at Cody, Wyo.: U. S. Geol. Survey Bull. 340-L, pp. 451-456.

Sulfur deposits are in hot-spring area along banks of Shoshone River, about 3 miles west of Cody. Some sulfur occurs in travertine terraces, but richest accumulations are in limestone just beneath the travertine. Hot springs have temperature of 98°F and contain large amounts of CO_2 and H_2S; sulfur was deposited from these sulfur-bearing waters. 850 tons of sulfur extracted from 2,833 tons of ore in 1906.

6. Woodruff, E. C., 1909, Sulphur deposits near Thermopolis, Wyom.: U. S. Geol. Survey Bull. 380-M, pp. 373-380.

Sulfur is associated with travertine (calcium carbonate and calcium sulfate) in terrace deposits of extinct hot springs, 3½ miles northwest of Thermopolis. Sulfur occurs as irregular masses that are probably fillings of old spring channels. Active springs near Thermopolis are now issuing H_2S and CO_2 gases. Deposits are similar, in hot spring origin and association with anticlinal structure, to deposits near Cody that are described by Woodruff. About 200 tons of sulfur had been produced from the deposit in the latter part of 1908.

Alaska

Akun Island - 1
Kanaga Island - 2
Makushin Volcano, Unalaska Island - 1
Mt. Hague, Pavlof Bay area - 2
Stepovak Bay area - 1

1. Maddren, A, G., 1919, Sulphur deposits on Unalaska and Akun Islands and near Stepovak Bay: U. S. Geol. Survey Bull. 692-E, pp. 283-298.

Describes three sulfur deposits of solfataric origin in southwestern Alaska: Makushin Volcano on Unalaska Island, Akun Island, and near Stepovak Bay on the Alaska peninsula. Deposits have not been mined, but were prospected during previous year.

At Makushin Volcano, sulfur occurs as incrustations and disseminations in altered basalt near center of the crater in an area of about 30 acres that seems to be permanently free of ice and snow. The surface crust (1-2 ft thick) with average content of 50 percent sulfur in richest parts, is estimated to contain 12,500 tons of sulfur; underlying zone contains about 4,900 tons of sulfur per acre. The deposit on Akun Island is associated with milder solfataric activity. Sulfur occurs as thin incrustations and disseminations in decomposed material. The sulfur-bearing mantle, average thickness of 2 ft and average content of 40 percent sulfur, is judged to contain 1,200 tons of sulfur per acre; area is between 15 and 20 acres. Deposit could be easily mined. Deposit near Stepovak Bay is apparently in extinct crater, but was not visited because of danger in crossing glacier. Sulfur occurs in morainic deposits derived from crater.

2. Robinson, G. D., and others, 1947, Alaskan volcano investigations Rept. no. 2, Progress of investigations in 1946: U. S. Geol. Survey, 105 pp.

Describes investigations of volcanos on Alaskan Peninsula and Aleutian Islands in 1946. Cones of sulfur 3 to 4 ft high occur with fumaroles on southwest side of Mount Hague, Pavlof area (p. 17). Gases from fumaroles on Umnak Island contain SO_2 and H_2S (pp. 42-49). Sulfur is associated with fumaroles at Kanaga Volcano (p. 93).

PYRITES

General

1. Ashley, G. H., 1920, Sulfur in coal, geological aspects: Am. Inst. Min. Met. Eng. Trans., vol. 63, pp. 732-738.

A brief general discussion on pyrites in coal.

2. Bain, H. F., 1906, Zinc and lead deposits of the upper Mississippi Valley: U. S. Geol. Survey Bull. 294, 155 pp.

A general paper largely devoted to the geology, ore deposits, and description of mines in Iowa, Wisconsin, and Illinois. Deposits lie in unaltered, flat-dipping dolomites and limestones in vertical fractures, "pitches and flats," and in thin disseminated bodies. Sulfides are sphalerite, marcasite, pyrite, galena, and sparse chalcopyrite.

3. International Geological Congress, 16th sess., 1935, Copper resources of the world, vol. 1 (North America), 441 pp., United States.

Includes descriptions by various authors of copper deposits in United States, Alaska, Canada, Mexico, Central America, and the West Indies. Pyrite occurs in notable quantities in many of the deposits. Bibliographies are given for the different reports.

4. Emmons, W. H., 1909, Some regionally metamorphosed ore deposits and the so-called segregated veins: Econ. Geology, vol. 4, pp. 755-781.

Describes the deposits at Blue Hill and Deer Isle, Maine, the Milan mine, and Ammonoosuc district, N. H., and Ely, Vt., with brief notes on the Davis mine, Mass., the Gossan Lead, Va., and Ducktown, Tenn. The Blue Hill deposits lie in schists and volcanic rocks, and are composed of massive pyrite with some chalcopyrite. The Milan deposits are overlapping pyritic lenses in schist. Sulfides are pyrite, chalcopyrite, sphalerite, galena, bornite, and chalcocite; much of the ore is massive pyrite with schist inclusions. In the Ammonoosuc district the lodes consist of pyrite, pyrrhotite and chalcopyrite. The deposits at Ely lie in schist and the sulfides are pyrrhotite and chalcopyrite, with minor pyrite and sphalerite; ore bodies at the Elizabeth mine are 35 to 100 ft wide. The pyritic vein at the Davis mine is 12-22 ft wide and 700 ft long; sulfides are pyrite, chalcopyrite, and pyrrhotite. Products of the ore are sulfuric acid and copper.

5. Newhouse, W. H., 1927, Some forms of iron sulphide occurring in coal and other sedimentary rocks: Jour. Geology, vol. 35, pp. 78-83.

Mineralogical study was made of iron sulfide samples from bands parallel to bedding, from lenses, and from joints in coal, and from concretions in other sedimentary rocks. The fine-grained iron sulfide that forms bands and lenses in coal appears to

be marcasite, whereas the iron sulfide in joints is pyrite. Iron sulfide concretions in other sedimentary rocks may be pyrite or marcasite.

6. Powell, A. R., and Parr, S. W., 1919, A study of the forms in which sulphur occurs in coal: Univ. Illinois Eng. Exp. Sta., Bull. 111, 62 pp.

New and more accurate methods of determining the various forms of sulfur in coal were developed. It was found that sulfur in coal occurs in four characteristic forms: resinic organic sulfur; humus organic sulfur; pyrite or marcasite; and sulfates--these are usually very scarce in freshly mined, unoxidized coal. Native sulfur was not found in any of the samples and is believed to be absent except in unusual places where it has formed as a decomposition product of pyrites. The constitution of coal is reviewed.

7. Ridgway, R. H., 1931, Pyrites: U. S. Bur. Mines Inf. Circ. 6523, 26 pp.

General information on pyrites: world sources and reserves, production and consumption, market and prices, imports and exports, and bibliography. Brief descriptions of U. S. pyrite mines producing in 1930, (Gossan Lead, Va.; Ducktown, Tenn.; Platteville district, Wisc.; Hornet and Leona Heights mines, Calif.; and Balmat mine, N. Y.). Index map of these producers, and location map of sulfuric-acid plants using pyrites.

8. Ross, C. P., 1927, Pyrite and sulfur in the United States, in Les reserves mondiales en pyrites: Internat. Geol. Cong., 14th sess., Madrid, vol. 2, pp. 589-598.

Summarizes information on the industry, reserves, and distribution of deposits.

9. Ross, C. S., 1935, Origin of the copper deposits of the Ducktown type in the Southern Appalachian region: U. S. Geol. Survey Prof. Paper 179, 165 pp.

Describes the mineralogy of the ores and discusses the origin of the cupriferous pyrrhotite deposits in the southern Appalachian region. Deposits studied include Ore Knob, Gossan Lead, Elk Knob, Otto, Cullowhee, Wayhutta, Savannah, Fontana, Ducktown district, and Stone Hill. Pyrrhotite is the principal sulfide, and is accompanied by variable amounts of pyrite, chalcopyrite, sphalerite, and magnetite; gangue minerals include quartz, silicates, and carbonates. Deposits were formed by hydrothermal replacement in a series of stages.

10. Smith, P. S., 1920, Chapter on sulphur, pyrites, and sulphuric acid; U. S. Geol. Survey, Mineral Resources U. S., 1917, pp. 19-62.

A description of pyrites deposits in the United States is given (as well as the statistical information customarily included in this annual volume which summarizes the results of an investigation of domestic sources of pyrites by the Geological Survey. This study was made because of the serious shortage of sulfuric acid during World War I. This report is still of considerable value, because many of the mines mentioned have been inactive since the end of World War I. Pyrites deposits are noted in 31 states; pyrite has been recovered from coal operations in 9 states.

11. Thiessen, Reinhardt, 1920, Occurrence and origin of finely disseminated sulfur compounds in coal: Am. Inst. Min. Met. Eng. Trans., vol. 63, pp. 913-931.

Minute spherical grains of pyrite are disseminated through most bituminous and sub-bituminous coals, lignites and peats. Sulfur also appears to occur in organic compounds. Believes that the sulfur in disseminated pyrite and organic compounds was originally accumulated by plants.

12. Weed, W. H., 1911, Copper deposits of the Appalachian States: U. S. Geol. Survey Bull. 455, 166 pp.

Cupriferous pyrite and pyrrhotite deposits described are in Maine, New Hampshire, Vermont, Massachusetts, Virginia, North Carolina, Georgia, Tennessee, and Alabama. Report is of value mainly as summary of these deposits, for many of the descriptions have been superseded by more recent articles.

13. Wendt, A. F., 1886, The pyrites deposits of the Alleghanies: Eng. and Min. Jour., vol. 41, pp. 407-410, 426-428, 446-447; vol. 42, pp. 4-5, 22-24; also School of Mines Quarterly, vol. 7, pp. 154-188, 218-235, 301-323.

Compares cupriferous pyrrhotite and pyrite deposits of eastern states with similar ones in Europe, and concludes they are of sedimentary origin. Ducktown deposits, and mining and smelting operations are described in detail. Deposits in Georgia; at Stone Hill, Ala.; Ore Knob, N. C.; southwest Virginia; Louisa County, Va.; Orange County, Vt.; Davis mine, Mass.; Milan mine, N. H.; Newfoundland, and Quebec are described.

14. Yancey, H. F., 1920, Some chemical data on coal pyrite: Chem. Met. Eng., vol. 22, pp. 105-109.

Presents chemical data on pyrites samples gathered by the different state geological surveys in their coal pyrites investigations of 1918. Gives sulfur content of pyrites samples from Ohio, Missouri, Indiana, Tennessee, Kansas, Kentucky, Illinois, Pennsylvania, and Michigan. Color and physical appearance are not indicative of sulfur content, but specific gravity is. Properly prepared pyrites concentrates do not contain injurious amounts of carbon. Coal pyrites contains only small amounts of arsenic and phosphorous.

15. Yancey, H. F., and Fraser, Thomas, 1921, The distribution of the forms of sulphur in the coal bed: Univ. Illinois Eng. Exp. Sta. Bull. 125, 92 pp.

One coal bed in Illinois and two in Kentucky were sampled and analyzed for organic sulfur and pyritic sulfur. Samples 1 to 2 ft long were taken across the full thickness of the coal beds at several places in the mine. In the no. 6 bed at the Middlefork mine, Ill., pyritic sulfur and total sulfur were generally highest near the bottom and near the top of

the bed. Samples from no. 12 and no. 9 coal beds in Kentucky show similar variation in sulfur distribution. Organic sulfur shows less variation than pyritic sulfur in its distribution.

Deposits in different states and Alaska

Alabama

McGee and Garrett prospects, Clay County - 1, 4
Pyriton dist., Clay County - 1,3, 4,; P 10, 12
Stone Hill mine, Randolph and Cleburne Counties - 1, 2, 5; P 9, 10, 12, 13

1. Adams, G. I., 1930, Gold deposits of Alabama and occurrences of copper, pyrite, arsenic, and tin: Alabama Geol. Survey Bull. 40, 91 pp.

Gold deposits of Alabama are described at length. Principal pyrite deposits are near Pyriton, Clay County, which were mined at different periods until 1919. Deposits here are cupriferous pyrite lenses in chlorite schist. Other occurrences of pyrite in chlorite schist and mica schist are noted. Pyrrhotite occurs in some abundance with chalcopyrite at the Stone Hill copper mine, which was worked for copper before 1897.

2. Pallister, H. D., and Thoenen, J. R., 1948, Stone Hill copper mine, Cleburne and Randolph Counties, Ala.: U. S. Bur. Mines Rept. Inv. 4221, 29 pp.

Stone Hill copper mine, principal copper producer in the state, was worked at intervals between 1874 and 1899. Ore consists of massive and disseminated sulfides, mostly pyrrhotite with some pyrite and chalcopyrite, in a mineralized zone about 800 ft long. Country rock is chlorite schist and hornblende gneiss. Deposit was explored by eight drill holes.

3. Pallister, H. D., and Thoenen, J. D., 1949, Investigation of copper-bearing pyrite ores, Pyriton, Clay County, Ala.: U. S. Bur. Mines Rept. Inv. 4494, 15 pp.

The Pyriton deposits were worked for copper prior to 1875; they were later worked for pyrite, being most productive during the period 1900-19. Pyrite and chalcopyrite occur in lenticular massive sulfide bodies in chlorite schist in a zone more than 1 mile long. Four vertical holes were drilled by the Bureau of Mines.

4. Prouty, W. F., 1923, Geology and mineral resources of Clay County, with special reference to the graphite industry: Alabama Geol. Survey County Rept. no. 1, 190 pp.

Rocks of the area include mica schists and gneisses, phyllites, chlorite-amphibole schists, and granitic rocks. Mineral deposits described are graphite, iron, manganese, mica, gold, arsenic, and pyrite. The principal pyrite deposits, the Pyriton deposits, are lenticular bodies in a zone several miles long in chlorite-amphibole schists. Pyrite was produced at several mines until the end of World War I.

5. Rothwell, R. P., 1877, The Stone Hill copper mine and works, Cleburne County, Ala.: Eng. and Min. Jour., vol. 24, pp. 86-88, 109, 130-131.

The Stone Hill deposit is similar to the cupriferous sulfide deposits of Ducktown, Ore Knob, and Vermont; copper and iron pyrites occur beneath the secondary black copper ore underlying the gossan. Deposit has been opened by an adit 400 ft long, and an incline 50 ft long. Proposed mining and smelting processes are discussed.

Arizona

Bisbee district, Cochise County - 2, 3, 7, 17, 23, 31, 32
Castle Dome mine, Gila County - 13, 15
Christmas mine, Gila County - 14, 21, 29
Clifton-Morenci district, Greenlee County - 3, 9
Courtland-Gleeson district, Cochise County - 30
Globe-Miami districts, Gila County - 1, 16, 18
Invincible prospect, Santa Cruz County - 22
Iron King mine, Yavapai County - 5, 10, 12, 31
Magma mine, Pinal County - 3, 26, 27, 31
Pima district (Sierrita Mountains), Pima County - 19, 31
Ray mine, Pinal County - 18
San Manuel mine, Pinal County - 4, 11, 24, 25, 28
United Verde mine, Yavapai County - 3, 6, 8, 10, 20

1. Bjorge, G. N., and Shoemaker, A. H., 1933, Applied geology at the Old Dominion mine, Globe, Gila County, Ariz., in Ore deposits of the Western States (Lindgren volume): Am. Inst. Min. Met. Eng., pp. 709-716.

Mainly a discussion of the methods of geological study at the Old Dominion mine, which was recently closed after 50 yr. of operation. Over 850,000,000 pounds of copper were produced from this mine and two adjoining properties on the Old Dominion vein, which was worked over a distance of 3 miles and to a depth of 2,200 ft. Major primary sulfides were pyrite, chalcopyrite, and bornite; good copper ore changed abruptly to pyritic ore along the strike and downward.

2. Bonillas, Y. S., Tenney, J. B., and Feuchere, Leon, 1916, Geology of the Warren mining district: Am. Inst. Min. Eng. Trans., vol. 55, pp. 284-355.

A comprehensive account of the geology and ore deposits of the Warren or Bisbee district. Ore deposits of various types and shapes occur in granite porphyry and in the surrounding sedimentary rocks. Principal types of alteration accompanying the ore deposits are silicification, sericitization, and chloritization. Pyrite is abundant in the different types of deposits; bornite, chalcopyrite, sphalerite, and galena are the other primary sulfide minerals. Oxidation and enrichment by ground waters has been profound; supergene minerals include siderite, chalcocite, malachite, and azurite.

3. Butler, B. S., and others, 1938, Some Arizona ore deposits; Part 1, General features; Part 2,

Mining districts: Arizona Bur. Mines Geol. Ser. No. 12, Bull. No. 145, 136 pp.

Presents papers given by 15 authors at Am. Inst. Min. Met. Eng. symposium on Arizona mines and mining districts. Pyrite is not specifically discussed. Descriptions are included of the following mines or districts where pyrite is an abundant mineral; Bisbee, Jerome, Clifton-Morenci and Magma.

4. Chapman, T. L., 1947, San Manuel copper prospect, Pinal County, Ariz.: U. S. Bur. Mines Rept. Inv. 4108, 93 pp.

Presents results of Bureau of Mines' drilling project at San Manuel prospect between Nov. 1943 and Feb. 1945. Exploration indicated that deposit was a tabular zone of disseminated chalcopyrite mineralization in quartz monzonite; the upper portion of the deposit is oxidized and enriched. A zone of pyritic mineralization lies in the footwall of the deposit. Drill logs, giving copper assay, rock type, and ore minerals for each 5-foot interval, constitute the greater part of the report.

5. Creasey, S. C., 1950, Iron King mine, Yavapai County, Ariz.: Arizona Bur. Mines Bull. 156, no. 2, pp. 112-122.

Mine is 12 miles east of Prescott in Big Bug mining district. Capacity of mill in 1948 was 500 tons. Deposit is a massive replacement of schist along 11 veins with sharp contacts against wallrock; stope length of minable ore ranges from 60 ft in individual veins to 1000 ft in composite veins. Central portion of veins is massive sulfide with sphalerite and galena as dominant ore minerals; north ends of veins are massive quartz; south ends of veins grade into high-pyrite and finally end in quartz-pyrite stringers. Table of production figures.

6. Hansen, M. G., 1930, Geology and ore deposits of the United Verde mine: Min. Cong. Jour., vol. 16, pp. 306-311, 312.

Describes the areal geology, and the United Verde pyritic copper deposit. All other aspects of the operation are also described in separate reports in this issue.

7. Head, R. E., and others, 1932, Statistical microscopic examination of mill products of the Copper Queen concentrator, of the Phelps Dodge Corp., Bisbee, Ariz.: U. S. Bur. Mines Tech. Paper 533, 48 pp.

Presents results of statistical microscopic study of mill feeds and flotation products of the Copper Queen concentrator. The ore is of the "porphyry" type containing considerable pyrite. Chalcocite is the chief copper mineral, and is very intimately associated with pyrite as coatings of and veinlets in the pyrite grains. Mineralogical analyses of the mill feeds and flotation products were made. Pyrite contents were as follows:

	Percent pyrite		Percent pyrite
Sand feed	29.36	Slime feed	10.82
Sand concentrates	80.79	Slime concentrates	65.88
Sand tailings	17.34	Slime tailings	4.75

8. Hewett, D. F., and others, 1936, Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, 197 pp.

Describes the lenticular and pipe-like sulfide replacement deposits at Jerome, Ariz. (See p. 28.) The United Verde Extension mine is reported to be nearing exhaustion; in the United Verde mine there are large reserves of copper ore in the pyritic mass. Prior to 1934 the United Verde Co. planned to mine the entire sulfide mass composed largely of pyrite and to recover Zn, Fe, S, H_2SO_4, and Se in addition to Cu, Au, and Ag.

9. Lindgren, Waldemar, 1905, Copper deposits of the Clifton - Morenci district, Ariz.: U. S. Geol. Survey Prof. Paper 43, 375 pp.

Pyrite is an abundant mineral in the district, being present in the different ore bodies, and occurring as disseminations and stringers in the country rock. A mass of nearly solid pyrite, about 50 ft thick, is found in the lower mine workings on the Joy vein; cupriferous pyrite is being mined from here for H_2SO_4 manufacture.

10. Lindgren, Waldemar, 1926, Ore deposits of the Jerome and Bradshaw Mountains quadrangles, Ariz.: U. S. Geol. Survey Bull. 782, 192 pp.

Describes the geology and the pyritic copper and gold-quartz-tourmaline replacement deposits near Jerome. United Verde orebody is an elliptical mass (800 by 700 ft in horizontal section) composed largely of quartz-porphyry replaced by pyrite and chalcopyrite; much massive pyrite with low copper values in which lie masses carrying 5-6 percent copper. Sulfides are pyrite and minor amounts of chalcopyrite, sphalerite, tennantite, and sparse arsenopyrite. United Verde Extension orebody (440 by 269 ft in horizontal section) carries much massive pyrite and chalcocite (10 percent of the ore). The Iron King mine, 1 mile west of Humboldt Smelter is in a series of lenses (100-500 ft long and 5-10 ft wide) in silicified schist; sulfides occur as streaks and are arsenopyrite, pyrite, sphalerite and sparse chalcopyrite.

11. Lovering, T. S., 1948, Geothermal gradients, recent climatic changes, and rate of sulfide oxidation in the San Manuel district, Ariz.: Econ. Geology, vol. 43, pp. 1-20.

Thermal gradients were measured in 11 churn drill holes at San Manuel. Two inflection points on the thermal gradient curves are interpreted to be related to climatic changes. Larger inflections occur where sulfides are at or above water table, and are due to oxidation of the sulfides. Pyrite content of sulfide in one hole averages 4.91 percent, and 3.58 percent in another hole.

12. Mills, H. F., 1948, Occurrence of lead-zinc ore at Iron King Mine, Prescott, Ariz.: Am. Inst. Min. Met. Eng. Trans., vol. 178, pp. 218-222.

Ore occurs as series of shoots in a shear zone in schist for a length of 3,500 ft; strike length of shoots ranges from 60 to 600 ft, and width ranges from 3 to 14 ft. Shoots are arranged en echeleon and increase in area and tonnage with depth. Sulfides are pyrite,

sphalerite, galena, tennantite, and sparse chalcopyrite and arsenopyrite. Pyrite constitutes nearly half the average mine ore and carries most of the gold values. A bulk flotation plant was erected in 1938 and operations have been continuous since; fluxing pyrite is recovered.

13. Peterson, N. P., Gilbert, C. M., and Quick, G. L., 1946, Hydrothermal alteration in the Castle Dome copper deposit, Ariz.: Econ. Geology, vol. 41, pp. 820-840.

Hydrothermal alteration of the quartz monzonite host rock in the Castle Dome copper deposit consists of three phases: weak propylitic alteration of mineralized area, clay alteration, and quartz-sericite alteration along quartz-pyrite veins. A zone of chalcopyrite mineralization occurs in argillized quartz monzonite, and is underlain by an extensive zone of quartz-sericite-pyrite mineralization. Samples of the argillized rock contain 1.7 percent pyrite; a sample of the quartz-sericite phase contains 7 percent pyrite.

14. Peterson, N. P., and Swanson, R. W., 1946, The Christmas copper mine, Gila County, Ariz.: Unpublished manuscript in open-files of U. S. Geol. Survey.

Describes results of geologic study made in cooperation with Bureau of Mines drilling program. Chalcopyrite occurs with pyrite and magnetite in contact metamorphosed limestone; pyrite and magnetite are particularly abundant near the contact with quartz-mica diorite.

15. Peterson, N. P., 1948, Geology of the Castle Dome copper deposit, Ariz.: Am. Inst. Min. Met. Eng. Tech. Pub. 2302, 11 pp.

The Castle Dome copper deposit in the Miami district is a porphyry type deposit in quartz monzonite. An elongate zone of chalcopyrite mineralization, over a mile long, is underlain by a zone of pyritic mineralization in which pyrite occurs in quartz veins. The copper orebody was formed by supergene enrichment in the chalcopyrite zone.

16. Ransome, F. L., 1903, Geology of the Globe copper district, Ariz.: U. S. Geol. Survey Prof. Paper 12, 168 pp.

Deposits are of several types: lodes in schist, granite, quartzite, and diabase; masses in limestone; and irregular bodies in shattered rocks. Pyrite occurs in abundance with chalcopyrite and oxidized copper ores, as in the Old Dominion mine. Ores mined up to 1901 had been mostly oxidized ores, and the character and distribution of primary sulfide ore was not well known when Ransome studied the area.

17. Ransome, F. L., 1904, The geology and ore deposits of the Bisbee quadrangle, Ariz.: U. S. Geol. Survey Prof. Paper 21, 168 pp.

Pyrite is the most abundant sulfide in the district and occurs in large quantities in the large bodies of copper ore in limestones around the porphyry mass south of Bisbee. In the lower mine levels pyrite forms extensive bodies which grade into altered limestone in which pyrite occurs as disseminations and stringers. Only those portions of pyritic bodies containing chalcopyrite or chalcocite have been mined.

18. Ransome, F. L., 1919, The copper deposits of Ray and Miami, Ariz.: U. S. Geol. Survey Prof. Paper 115, 192 pp.

The disseminated copper deposits of the Ray and Miami districts are large gently dipping tabular masses in schist, granite porphyry, and quartz monzonite porphyry. The ore has been formed by supergene chalcocite enrichment, and is overlain by a zone that contains oxidized copper minerals in places and that is leached of copper minerals elsewhere. The protore lying beneath the ore bodies consists of primary chalcopyrite and pyrite occurring in innumerable small fissures; pyrite is the most abundant sulfide mineral.

19. Ransome, F. L., 1922, Ore deposits of the Sierrita Mountains, Pima County, Ariz.: U. S. Geol. Survey Bull. 725-J, pp. 407-428.

A general description of the geology of the region and the ore deposits of the Pima and Papago districts. Copper, lead, zinc, silver, and gold have been produced from the Pima district. The ore bodies are mainly contact metamorphic deposits in limestone. Pyrite is abundant at the Mineral Hill, Glance, Queen, and Senator Morgan mines.

20. Reber, L. E., Jr., 1922, Geology and ore deposits of the Jerome district: Am. Inst. Min. Met. Eng. Trans., vol. 66, pp. 3-26.

Three large, massive sulfide deposits occur in schists at Jerome, Ariz. Pyrite predominates, followed by chalcopyrite and minor sphalerite; sulfides carry gold and silver, and gangue is jaspery quartz. Country rock replaced is quartz porphyry, greenstone, and chloritic schists. Ore of United Verde Extension is chiefly chalcocite and pyrite and ranges from high-copper to high-pyrite sulfide in the chalcocite zone. The primary sulfide zone minerals are chiefly quartz, pyrite, chalcopyrite, and sphalerite. States that about four-fifths of the massive sulfides are low grade.

21. Ross, C. P., 1925, Ore deposits of the Saddle Mountains and Banner mining districts, Ariz.: U. S. Geol. Survey Bull. 771, 72 pp.

Ore deposits include lead-silver veins, pyritic gold deposits on shear zones, disseminated pyrite deposits, and contact metamorphic deposits. Principal mine is the Christmas copper mine, where magnetite, chalcopyrite, and pyrite occur in garnet rock in contact-metamorphosed limestone.

22. Schrader, F. C., 1915, Mineral deposits of the Santa Rita and Patagonia Mountains, Ariz.: U. S. Geol. Survey Bull. 582, p. 257.

Disseminated chalcopyrite and veinlets of pyrite occur in nearby massive porphyritic rhyolite at the Invincible prospect. Concentrates are reported to average 35 to 36 percent sulfur and 33 percent iron.

23. Schwartz, G. M., and Park, C. F., Jr., 1932, A microscopic study of ores from the Campbell mine, Bisbee, Ariz.: Econ. Geology, vol. 27, pp. 39-51.

Mainly a description of the ores from the recently developed Campbell ore body. In the specimens studied chalcopyrite and bornite were more abundant than pyrite. In the brief description of the deposit, it is stated that the copper deposits on the lower levels occur around the periphery of a mass of pyrite.

24. Schwartz, G. M., 1945, Geology of the San Manuel area, Pinal County, Ariz.: U. S. Geol. Survey Strategic Minerals Investigations, Prelim. Maps 3-180.

The geologic features of the San Manuel copper deposit are described in a brief text and are shown in detailed maps and sections; the information on the ore deposit is based mainly upon study of drill cuttings from Bureau of Mines drilling program. The ore body is of the porphyry type in monzonite, and most of it is covered by younger conglomerate. It appears to be a steeply dipping tabular mass, and is oxidized in its upper part; chalcopyrite is the primary sulfide mineral. A zone of strong alteration and pyrite mineralization lies in the footwall of the deposit.

25. Schwartz, G. M., 1949, Oxidation and enrichment in the San Manuel copper deposit, Ariz.: Econ. Geology, vol. 44, pp. 253-277.

A study based mainly on the mineralogy of the drill cuttings from the oxidized and enriched zones of the San Manuel deposit. The latest available information on the geology and structure of the deposit is also given. The highly pyritic zone in the footwall of the deposit is discussed briefly; the top of that zone is shown in several sections.

26. Short, M. N., and Ettlinger, I. A., 1927, Ore deposition and enrichment at the Magma mine, Superior, Ariz.: Am. Inst. Min. Met. Trans., vol. 74, pp. 174-222.

Geology, ore deposits, and mineralogy are described. Magma vein is a strong ore body formed by replacement of wall rock (limestone, quartzite, diabase) along fault zone. Pyrite is most abundant sulfide, being 10 to 20 times as abundant as copper sulfides in places. Bornite, chalcopyrite, and chalcocite are main copper minerals; pyrite content is usually low where bornite is abundant.

27. Short, N. N., and others, 1943, Geology and ore deposits of the Superior mining area, Ariz.: Arizona Bur. Mines Geol. Ser., no. 16., Bull. 151, 159 pp.

Most of the ore deposits are replacement veins in faults that cut limestone, quartzite, diabase, and schist. The Magma vein is the principal vein, and has been the most productive deposit; values have been mainly copper and silver, with some gold and zinc. Pyrite is the chief sulfide in much of the vein, although it is a minor constituent in some parts of the vein. Chalcopyrite, enargite, and bornite are the main copper minerals and are accompanied by some hypogene chalcocite; sphalerite is abundant in certain parts of the vein. Rock temperatures increase markedly with depth, reaching a temperature of 152° F. on the 4,800 level; special ventilating and air conditioning measures have been taken to reduce underground air temperatures.

28. Steele, H. J., and Rubly, G. R., 1947, San Manuel prospect: Am. Inst. Min. Met. Eng. Tech. Pub. 2255, 12 pp.

Describes the geology of the San Manuel copper prospect in the Old Hat mining district, Pinal County, Ariz., and the drilling and sampling methods used in exploring the deposit since 1943. The deposit is of the "porphyry" type in quartz monzonite; its outcrop is small because most of the area is covered by younger conglomerate. Chrysocolla is the chief copper mineral in the oxidized zone, chalcocite is the main copper mineral in the secondary zone, and chalcopyrite in the primary zone. Drilling has shown strong pyritic mineralization in a footwall zone 2,200 ft wide.

29. Tainter, S. L., 1948, Christmas copper deposit, Gila County, Ariz.: U. S. Bur. Mines Rept. Inv. 4293, 58 pp.

Ore deposits occur in zones of garnetization in favorable limestone beds adjacent to a quartz diorite intrusion. Pyrite and magnetite are abundant in a belt less than 25 ft from the contact; chalcopyrite is most abundant in garnetized rock beyond this belt. Numerous holes were drilled by the Bureau of Mines from underground workings.

30. Wilson, E. D., 1927, Geology and ore deposits of the Courtland-Gleeson region, Ariz.: Arizona Bur. Mines Bull. 123, 79 pp.

Geology and ore deposits of Courtland-Gleeson or Turquoise district are described. Irregularly-shaped cupriferous pyrite deposits occur in dolomitic limestone, shale, and limestone near quartz monzonite porphyry. Portions of the deposits are oxidized and enriched. Pyrite occurs abundantly in all the ore deposits of the district and also as fine disseminations in quartz monzonite porphyry.

31. Wilson, E. D., and others, 1950, Arizona zinc and lead deposits, part 1: Arizona Bureau of Mines Geol. Ser. no. 18, Bull. 156, 144 pp.

The zinc and lead deposits of the state are described by various authors familiar with the deposits. Those containing appreciable amounts of pyrite are in the Bisbee or Warren district, Pima district, Superior area, and Iron King mine.

32. Wittenau, E., and Cramer, W. B., 1931, Milling methods and costs at the Copper Queen concentrator of the Phelps Dodge Corp., Bisbee, Ariz.: U. S. Bur. Mines Inf. Circ. 6404, 29 pp.

Describes milling methods of Copper Queen concentrator, which was treating 4,000 tons of ore daily in 1929. Ore was porphyry type mined from Sacremento Hill, and East and Southwest Extension ore bodies. Principal copper mineral is chalcocite, occurring as coatings of and veinlets in pyrite. The pyrite content of mill heads in 1929 was about 19 percent.

Arkansas

Berryville (Newman) prospect, Carroll County - 1, 2
Caddo Gap, Montgomery County - 3
Hot Springs, Garland County - 4

1. Branner, G. C., and others, 1940, Mineral resources of Benton, Carroll, Madison, and Washington Counties: Arkansas Geol. Survey County Min. Rept. 2, 55 pp.

Pyrite deposit on Newman farm near Berryville is elliptically shaped tabular body in dolomite of Ordovician age. Deposit was explored by 25 drill holes in 1937-38. Drill logs, map, and sections are included. Ore reserves are estimated to be equivalent of 284,58 tons of pyrite concentrates with 42 percent sulfur content; most of this is in ore that contains between 23 and 32 percent sulfur. Pyrite also occurs on the Van Hook farm, 1 1/8 miles to the southeast, and at a locality between the two farms.

2. Branner, G. C., 1942, Mineral resources of Arkansas: Arkansas Geol. Survey Bull. 6, pp. 39-40.

Very brief mention of pyrite in Arkansas. Largest deposit is near Berryville, Carroll County; other deposits are at Yellville, Marion County, and at Magnet Cove, Hot Spring County.

3. Miser, H. D. and Purdue, A. H., 1929, Geology of the DeQueen and Caddo Gap quadrangles, Ark.: U. S. Geol. Survey Bull. 808, 195 pp.

Brief notes on a pyrite deposit consisting of marcasite and pyrite masses and veins in shales. Shallow pits have been dug and three shallow holes drilled. Deposit has not been proved to be of minable size.

4. Purdue, A. H., and Miser, H. D., 1923, U. S. Geol. Survey Geol. Atlas, Hot Springs, Ark., folio, (no. 215), p. 11.

Pyrite veins, as much as 4 in. thick, form mineralized zone about 30 ft wide in Hot Springs sandstone, on south slope of West Mountain, 2 miles west of Hot Springs.

California

Afterthought mine, Shasta County - 1, 5, 10, 11
Alma mine, Alameda County - 1, 5, 7, 9, 14, 19, 23; P 7, 10
American Eagle-Blue Moon mines, Mariposa County - 5, 27
Balaklala mine, Shasta County - 1, 5, 10, 11, 12
Big Bend mine, Butte County - 5
Blue Ledge mine, Siskiyou County - 1, 2, 5, 15, 23, 26
Bully Hill mine, Shasta County - 1, 5, 10, 11, 12
Buzzard Hill mine, Siskiyou County - 2, 5
Copper King mine, Fresno County - 1, 5, 20
Copperopolis district, Calaveras County - 1, 5, 18, 25, 27
Dairy Farm mine, Placer County - 1, 5, 20; P 10
Eagle Mountains mine, Riverside County - 6
Fresno Copper mine, Fresno County - 1, 5, 20
Friday mine, San Diego County - 5, 8, 23
Gray Eagle mine, Siskiyou County - 2, 5
Green Mountain mine, Mariposa County - 1, 5, 20
Iron Mountain (Hornet) mine, Shasta County - 1, 5, 10, 11, 12, 13, 16, 17, 23, 24
Island Mountain mine, Trinity County - 1, 3, 5
Leona Heights mine, Alameda County - 1, 5, 7, 9, 14, 19, 21, 22, 23; P 7, 10
Mammoth mine, Shasta County - 1, 5, 10, 11, 12
Newton mine, Amador County - 1, 5, 27
Penn mine, Calaveras County - 1, 5, 18, 27
Quail Hill area, Calaveras County - 5, 18, 27
Redwood Copper Queen mine, Mendocino County - 1, 5
Shasta King mine, Shasta County - 1, 5, 10, 11, 12
Spenceville mine, Nevada County - 1, 5, 18, 20
Vulcan deposit, San Bernardino County - 6

1. Aubury, L. E., 1908, The copper resources of California: California Min. Bur. Bull. 50, 366 pp.

The condition of the industry, history, and production are discussed, followed by descriptions of the copper deposits in Shasta County, the Coast Range, the Sierra Nevada belt, and in the southeast portion of the State. The deposits which carry appreciable amounts of pyrite are as follows: Alma and Leona Heights, Alameda County; Newton Mine, Amador County; Union and Keystone mines, Calaveras County; Fresno Copper and Copper King mines, Fresno County; Green Mountain, Mariposa County; Redwood Copper Queen, Mendocino County; Spenceville, Nevada County; Dairy Farm, Placer County; Bully Hill, Iron Mountain-Hornet, Mammoth, and Shasta King Mines, Shasta County; and Blue Ledge, Siskiyou County.

2. Averill, C. V., 1935, Mines and mineral resources of Siskiyou County: California Jour. Mines and Geology, vol. 31, pp. 255-338.

The principal pyritic deposits in Siskiyou County are at the Blue Ledge, Gray Eagle, and Buzzard Hill mines. The Blue Ledge ore body is in mica schist, has an average width of 5 ft, is 1,800 ft long, and has been opened to a depth of 600 ft. Principal sulfides are pyrite and chalcopyrite. About 9,000 tons of sorted ore averaged 13.7 percent Cu, 5.5 oz Ag per ton, 0.1 oz Au per ton, 30 percent Fe, and 30 percent S. Mine was closed in 1920. At the Gray Eagle mine, the ore is mainly chalcopyrite, except for high pyrite ore on the no. 7 adit level. At the Buzzard Hill mine, hundreds of feet of development have been done in gold bearing gossan and in the underlying body of heavy pyrite.

3. Averill, C. V., 1941, Mineral resources of Trinity County: California Jour. Mines and Geology, vol. 37, pp. 23-24.

Brief mention of the copper deposit at Island Mountain in the southwest part of the county. Property was reported to contain 275,000 tons of proved ore, having $3\frac{1}{2}$ percent Cu. This ore contains $1\frac{1}{2}$ oz Ag and $2.00 Au per ton. Shipped 1,000 tons per month until 1918. County rock is sedimentary series.

4. Bradley, P. R., 1913, Pyrites deposit in Plumas County, Calif.: Min. Met. Soc. America Bull. 65, pp. 276-278.

Brief discussion of an unnamed deposit in Plumas County and its comparison with the Leona Heights deposit.

5. Bramel, H. R., and others, 1948, Copper in California: California Div. Mines Bull. 144, 429 pp.

The pyritic copper and copper-zinc deposits of the Sierran foothill belt, investigated by the U. S. Geological Survey during World War II, are described in detail in part 1 of this volume; sixty mine maps and sections accompany the report. A general account of the belt is given, with descriptions of the following: Big Bend, Lilyama, Pioneer, Newton, Penn, Jesse Belle, and La Victoria mines, and the Grayhouse, Copperopolis, Quail Hill, and American Eagle-Blue Moon areas. Marketing and metallurgy of California copper-zinc-lead ores are discussed in part 2. All the copper mines in the State are listed in part 3, with notes on production, the owner, or operator, location of the mine, and remarks and literature references. The mines are also shown on a large index map of the State. A 28-page bibliography is included.

6. Burchard, E. F., and others, 1948, Iron resources of California: California Div. Mines Bull. 129, 304 pp.

The iron deposits of the State are described by various authors. Two large-sized contact metamorphic deposits have appreciable pyrite in the fresh unweathered ore: Eagle Mountains deposit, Riverside County (average pyrite content of fresh ore is 3-4 percent), and Vulcan deposit, San Bernardino County (as much as 3.77 percent sulfur in drill samples.)

7. Clark, C. W., 1917, The geology and ore deposits of the Leona rhyolite: California Univ., Dept. Geol. Sci., Bull. 10, pp. 361-382.

Discusses the petrography of the Leona rhyolite and the pyrite deposit. Two mines were in operation in 1917 near Leona Heights, east of Oakland; the Leona Heights(?) mine is described. This ore body is oval-shaped and contains soft ore and hard ore. The former is massive pyrite and is surrounded by gouge; the latter is silicified, contains more chalcopyrite, and is not bounded by gouge. The ore body appears to plunge toward the northeast, and it is inferred that shale underlies the present workings.

8. Creasey, S. C., 1946, Geology and nickel mineralization of the Julian-Cuyamaca area, San Diego County, Calif.: California Div. Mines Bull. 42, pp. 15-29.

Describes the nickel-bearing pyrrhotite deposit of the Friday mine and the history, development, and ore reserves of the mine. The deposit is an irregular mineralized zone, 6 to 20 ft wide and 55 ft long, formed by replacement of gabbro along the side of a schist inclusion. Pyrrhotite is the most abundant sulfide, and is accompanied by pentlandite, violarite, pyrite, and chalcopyrite. A grab sample assayed 11.75 percent Fe, 0.10 percent Cu, 0.15 percent Co, and 1.98 percent Ni. Ore reserves between the 132- and 180-foot levels are estimated at 5,000 tons of indicated ore.

9. Davis, F. F., 1950, Mines and mineral resources of Alameda County, Calif.: California Jour. Mines and Geol., vol. 46, pp. 305-307.

Alma pyrite mine was worked from 1891 to 1921, and the Leona Heights mine from about 1895 to 1934. Lenses of massive pyrite occurred in rhyolite. One of the reasons for closing mines was the repeated mine fires due to spontaneous combustion of pyrite.

10. Diller, J. S., 1903, Copper deposits of the Redding region, California: U. S. Geol. Survey Bull. 213, pp. 123-132.

Describes the rocks of the copper belt of Shasta County, and the ore deposits of the Afterthought, Bully Hill, Black Diamond, and Iron Mountain districts. In the Bully Hill district the ore bodies are irregularly distributed in shear zones as lenticular or sheetlike nodules from an inch to hundreds of feet long and as much as 20 ft wide. The ore is largely pyrite with some chalcopyrite and variable amounts of sphalerite; the gangue is chiefly barite. In the Iron Mountain district the ore bodies at the Iron Mountain and Hornet mines are lenticular pyritic copper bodies in shear zones in metarhyolite schist. The Balaklala, a large pyritic ore body, and the Shasta King deposits lie in the northern part of the Iron Mountain district.

11. Diller, J. S., 1906, U. S. Geol. Survey Geol. Atlas, Redding folio (no. 138), 14 pp.

The regional geology and mineral deposits are described. The pyritic copper deposits occur in the Bully Hill, Afterthought, Black Diamond, and Iron Mountain districts.

12. Graton, L. C., 1910, The occurrence of copper in Shasta County, Calif.: U. S. Geol. Survey Bull. 430-B, pp. 71-111.

The geology of the region, and the pyritic copper deposits of the Iron Mountain, Little Backbone, and Bully Hill districts are discussed. Ore lenses are considered to be replacement deposits in alaskite porphyry along brecciated shear zones. Pyrite is the most abundant sulfide; chalcopyrite and sphalerite are present in variable amounts. Gangue minerals are quartz, calcite, and barite.

13. Hershey, O. H., 1915, The geology of Iron Mountain: Min. and Sci. Press, vol. 111, pp. 633-638.

Describes the sedimentary, volcanic and igneous rocks, silicified and pyritized areas, gossan, and some iron ore occurrences in the vicinity of the Iron Mountain and Hornet mines. Below the zone of oxidation the pyrite varies from a sparse dissemination to nearly massive pyrite with quartz gangue. Locally the replacement by pyrite and other sulfides of the original rock is almost complete in the altered alaskite porphyry. The original distribution of the sulfide bodies was confined to a broad belt trending northeastward in the main porphyry intrusion; bodies are roughly lenticular and their attitude ranges from flat to steeply dipping.

14. Huguenin, Emile, and Costello, W. O., 1921, Alameda County: California Min. Bur. Rept. 17, pp. 32-33.

Leona Heights pyrite deposits lie about 4 miles southeast of Oakland City Hall and have been mined for many years solely for use in the manufacture of acid. The ore carries small masses of chalcopyrite with the pyrite. This deposit is very irregular, considerably faulted and is 10-30 ft wide. An average of 400 tons of ore running at least 46 percent sulfur was produced monthly. The Alma ore body, about 1 mile north of Leona Heights, is 12-18 ft in width.

15. Hundhausen, R. J., 1947, Blue Ledge copper-zinc mine, Siskiyou County, Calif.: U. S. Bur. Mines Rept. Inv. 4124, 16 pp.

The mine is in Elliott mining district, 3 miles south of the Oregon line and 39 miles south of Medford. The main ore zone is 1,680 ft long and 600 ft deep and lies in a belt of schist; lode of disseminated pyrite lies 10-20 ft from the hanging wall of the ore body. Other large pyrite veins occur in the district. The ore bodies are replacement lenses, stringers, and bands along shear zones. Sulfides in order of abundance are pyrrhotite, pyrite, chalcopyrite, and sphalerite; gangue is altered wall rock, quartz, and some calcite. Brief notes on sampling, diamond drilling, and the metallurgical and flotation tests done by the Bureau of Mines.

16. Kett, W. F., 1947, Fifty years of operation by the Mountain Copper Co., Ltd., in Shasta County, Calif.: California Jour. Mines and Geology, vol. 43, pp. 105-162.

An historical account of the Mountain Copper Co. operations covering the following subjects: The Old Iron Mountain mine, wartime production of copper and zinc, No. 8 mine and the Minnesota mill, extraction and treatment of low-grade old mine filling, decline of the smelter at Keswick, the Hornet mine, fires, gossan operation, and a brief description of the general geology.

17. Kinkel, A. R., Jr., and Albers, J. P., 1951, Geology of the massive sulfide deposits at Iron Mountain, Shasta County, Calif.: California Div. Mines, Special Rept. 14, 19 pp.

Ore bodies at the Iron Mountain mine are large lenses of massive pyrite containing chalcopyrite and sphalerite with minor amounts of Au and Ag. Deposits occur in rhyolite; ore bodies range in size from a few thousand tons to over 5 million tons and seem to be faulted segments of a body originally 4,500 ft long. Minable bodies of ore are closely associated with pre-ore feeder channels along faults in synclinal trough of volcanics. Main ore controls are a gently pitching anticlinorium with impervious shales overlying the ore zone. The gossan of the deposit was mined for silver prior to 1897, when mining of the massive sulfides for copper, and later pyrite, was started. About 3,600,000 tons of pyrite has been mined.

18. Knopf, A., 1906, Notes on the copper belt of the Sierra Nevada: Univ. California Geol. Bull. 4, no. 17, pp. 411-423.

Brief notes on the geology and mineralogy of the Spenceville and Pine Hill deposits in Nevada County, the Valley View group in Placer County, and the Campo Seco, Copperopolis, and Napoleon mines in Calaveras County. These deposits are closely associated with meta-andesites and were formed by replacement along shear zones.

19. Laizure, C. M., 1929, San Francisco field division-- Alamada County: California Div. Mines Rept. 25, pp. 427-456.

The Alma mine started in 1892 and was worked more or less continuously until 1921. The Leona Heights "new ore body" has a thickness of 25 ft and is overlain by 60-80 ft of overburden; thickest ore body found was 40 ft. The pyrite carries about 47 percent S, 1 percent Cu and contains $1.00 to $2.00 in gold (Au) per ton, but only the sulfur has been recovered.

20. Lang, Herbert, 1907, The copper belt of California: Eng. and Min. Jour., vol. 84, pp. 909-913, 963-966, 1006-1010.

Discusses the geology of the region, the mineral deposits and their ores, and the smelting practices. Pyrite and pyrrhotite are the principal sulfides and are accompanied by chalcopyrite and sphalerite. Author believes that pyrite prevails in the northern part of the belt, pyrrhotite in the southern part. In the Fresno mine 70 percent of the weight of the ore is pyrrhotite; it is also present at the Green mountain, the Buchanan, and the Daulton mines. The high-pyrite mines are the Dairy Farm and the Spenceville. The ore at the Newton mine and the Copper King mine is a cupriferous pyrite.

21. Lawson, A. C., 1914, U. S. Geol. Survey Geol. Atlas, San Francisco folio, (no. 193), 24 pp.

Gives a brief account of the mines at Leona Heights near Laundry Farm southeast of Oakland. Pyrite occurs as massive bodies of irregular shape with occasional small horses of country rock. The ore consists of pyrite with chalcopyrite and pyrrhotite.

22. Mace, C. H., 1911, Genesis of Leona Heights ore deposits, California; Min. and Eng. World, vol. 35, p. 1320.

Deposits are in rhyolite at Leona Heights near Oakland. Ore is a contact pyrite deposit along the crest and eastern flank of an anticline of shale. Overlying rock is a gossan from the oxidation of rhyolite with disseminated pyrite; underlying rock is black shale. Concludes that ore was derived from hanging-wall rock. Shipping analyses show 46-49 percent S and 2-3 percent Cu; also $2.00 Au per ton.

23. California Div. Mines, 1950, Mineral commodities of California, Bull. 156, 443 pp.

Pyrites is discussed on pages 203-206, sulfuric acid on p. 275. Major pyrite deposits are in Shasta and Alameda Counties. The principal producer at present is the Hornet mine, Shasta County; the mines in Alameda County were formerly important producers, but have been closed for many years.

Large pyrite deposits in the Dillon Creek area, Siskiyou County are now being developed. Massive pyrrhotite bodies with minor amounts of chalcopyrite and pyrite occur in Orange, San Diego, and Trinity Counties; the pyrrhotite ore at the Friday mine, Julian district, San Diego County is nickel bearing. The production of pyrite in California and in the entire U. S. during the years 1898-1946 is shown in a chart.

24. O'Brien, J. C., 1948, Current and recent mining activities in the Redding district: California Jour. Mines and Geology, vol. 44, pp. 356-357.

Gives recent account of the mining operations of the Mountain Copper Co., Ltd.

25. Reid, J. A., 1907, The ore deposits of Copperopolis, Calaveras County, Calif.: Econ. Geology, vol. 2, pp. 380-417.

Describes the general geology of the region and the ore deposits of the North Keystone, Union, and Empire sections. Chalcopyrite and pyrite occur in series of overlapping lenses in chlorite schist. The ore shoots are several hundred feet long and as much as 60 ft wide; copper ore in the center of the shoots grades into pyritic ore on the borders.

26. Shenon, P. J., 1933, Copper deposits in the Squaw Creek and Silver Peak districts and at the Almeda mine, southwestern Oregon with notes on the Pennell & Farmer and Banfield prospects: U. S. Geol. Survey Circ. 2, 35 pp.

Includes a brief description of the ore deposits of the Blue Ledge mine in California, situated 3 miles south of the Oregon line. Ore consists of low-grade pyritic ore and copper-zinc ore as large lenses in schist. The lenses range from a few feet to several hundred feet in length and up to 12 ft in width; drill holes have partly explored a large pyritic ore body about 30 ft wide. The chief sulfides are pyrite, pyrrhotite, sphalerite, and chalcopyrite, and the gangue is schist fragments and quartz; pyrrhotite constitutes over 50 percent, and sphalerite 25-30 percent of sulfides. Mine is developed to depth of 800 ft. About 150,000 tons of ore are indicated in the mine, and 50,000 tons are in the dumps.

27. Wiebelt, F. J., and others, 1951, Investigation of West Belt copper-zinc mines, El Dorado, Amador, Calaveras, and Mariposa Counties, Calif.: U. S. Bur. Mines Rept. Inv. 4760, 62 pp.

Summarizes results of Bureau of Mines' exploration of following mines: Copper Hill, Newton, Gray House, Constellation, North Keystone, Collier, and American Eagle mines. Ore bodies are sulfide lenses in schist; principal sulfides are chalcopyrite, sphalerite, and pyrite. Drill logs are given, but no sulfur assays.

Colorado

Camp Bird mine, Ouray County - 4, 14
Central City-Idaho Springs districts, Clear Creek and Gilpin Counties - 12, 14; P 10
Climax mine, Lake County - 2, 14
Gilman (Red Cliff) district, Eagle County - 3, 7, 11, 14.
Kokomo district, Summit County - 7, 9, 14
La Plata district, La Plata County - 5, 14
Leadville district, Lake County - 6, 7, 10, 14
Minnesota mine, Clear Creek County - 12, 14
Rico district, Dolores County - 7, 8, 13, 14
Uncompahgre district, Ouray County - 1, 14
Wellington mine, Summit County - 12, 14

1. Burbank, W. S., 1941, Structural control of ore deposition in the Uncompahgre district, Ouray County, Colo., with suggestions for prospecting: U. S. Geol. Survey Bull. 906-E, pp. 189-265.

Pyritic deposits occur within a mile of the intrusive center and consist of: magnetite-pyrite ores with a little copper and gold; pyritic ores containing copper and gold; and pyritic base-metal ores containing native gold, and gold and silver tellurides.

2. Butler, B. S., and Vanderwilt, J. W., 1933, The Climax molybdenum deposit, Colorado: U. S. Geol. Survey Bull. 846-C, pp. 195-237.

The Climax deposit lies in granite and is composed of a silicified and highly altered core surrounded by moderately altered rock which is cut by quartz veinlets carrying molybdenite. Veinlets of pyrite cut the core, the ore zone, and the outer zone of slightly altered rock. Pyrite also occurs disseminated in altered rock throughout the area and is the most abundant sulfide.

3. Crawford, R. D., and Gibson, Russell, 1925, Geology and ore deposits of the Red Cliff district, Colorado: Colorado Geol. Survey Bull. 30, 89 pp.

Pyrite occurs in nearly all the sulfide ore bodies in the district and generally carries Au, Ag, or Cu; most of it is massive in the large ore bodies and parts of a body may be composed of porous pyrite constituting over 75 percent of the volume. Most of the production has come from the replacement ore deposits in limestone and quartzite. Disseminated pyrite in the wall rock locally occupies 10-20 percent of the volume. Largest replacement body has a length of 3,000 ft and deposits vary from 3 to 100 ft thick. Chief sulfides are pyrite, sphalerite, and chalcopyrite.

4. Deshayes, E. V., and Young, W. E., 1948, Camp Bird lead-zinc deposits, Ouray County, Colo.: U. S. Bur. Mines Rept. Inv. 4230, 19 pp.

Considerable gold has been mined from upper part of vein. Pyrite becomes abundant in depth, and sulfides of copper, lead, and zinc are present locally in minable amounts. Seven holes were drilled by the Bureau of Mines; no commercial ore was found, but a large body of low-grade zinc ore was indicated.

5. Eckel, E. B., 1949, Geology and ore deposits of the La Plata district, Colo.: U. S. Geol. Survey Prof. Paper 219, 179 pp.

Pyrite is the most abundant sulfide in the deposits. At the Doyle mines, a bed of limestone several feet thick is replaced by pyrite.

6. Emmons, S. F., Irving, J. D., and Loughlin, G. F., 1927, Geology and ore deposits of the Leadville mining district, Colo.: U. S. Geol. Survey Prof. Paper 148, 368 pp.

The two classes of sulfide ores are sphalerite-pyrite-galena ore and pyrite ore (massive and disseminated) with enough Au, Ag, Cu, and Pb to justify shipping. Considerable pyrite has also been shipped (1906-21) for the manufacture of sulfuric acid; the residue was sold to smelters. Pyritic ores are often massive pyrite with minor quantities of other sulfides; such bodies occur in the Iron Hill, Carbonate Hill, Graham Park, Breece Hill, and Evans Gulch. Many ore bodies composed mainly of mixed sulfides carry bands or irregular masses of pyrite. Pyrite is the principal ore mineral at the margins of the blanket replacement deposits. Some large pyrite bodies are in the Maid, R. A. M., Greenback, Mahala, Tucson, and Wolftone mines.

7. Henderson, C. W., 1926, Mining in Colorado: U. S. Geol. Survey Prof. Paper 138, pp. 60-61.

Pyrite and sulfide ores from Leadville, Kokomo, Red Cliff, and Rico districts, and from Clear and Gilpin Counties have been used in sulfuric acid manufacture.

8. King, W. H., and Allsman, P. T., 1950, Reconnaissance of metal mining in the San Juan region; Ouray, San Juan, and San Miguel Counties, Colo.: U. S. Bur. Mines Inf. Circ. 7554, 109 pp.

The region is an important gold, silver, lead, and zinc producing area. Mineral deposits are described briefly and mining and milling operations discussed. Pyrite is an important constituent of the ores of many of the deposits.

9. Koschmann, A. H., and Wells, F. G., 1946, Preliminary report on the Kokomo mining district, Colorado: Colorado Sci. Soc. Proc., vol. 15, no. 2, pp. 103-106.

Deposits of the Kokomo district are high-temperature replacement bodies in limestone, and veins. Ore bodies are irregular in size and shape, as much as 15 ft in thickness; and ranging from a few feet to 300 ft in width. Some extend 2,000 ft down the dip of the beds. Minerals are pyrite, pyrrhotite, marcasite, marmatite, galena, and chalcopyrite with sparse gangue. Pyrrhotite ore consists of massive pyrrhotite with pyrite and sparse chalcopyrite; pyrite ore is composed of pyrite and some marcasite and sparse marmatite. Large deposits of pyrites are present in the Victory, Michigan, Uthoff, Kimberly-Wilfley, and Wintergreen mines.

10. Lee, H. S., 1920, Pyrite deposits of Leadville, Colo.: Am. Inst. Min. Eng. Trans., vol. 61, pp. 66-70.

The larger pyritic ore bodies in the Leadville district occur in a zone 6,000 ft long and several hundred feet wide that extends from the Yak and Moyer mines on the south to the Quadrilateral, Denver City, and Tip Top mines on Fryer Hill. Deposits are all enclosed by shells of manganiferous siderite and carry Zn, Au, and Ag enrichment zones. Small shipments of pyrite have been made to chemical plants in Colorado. Ore shipped from southern part of the district carried 42-49 percent S and contained more Zn than ore from the northern part.

11. Lovering, T. S., and Tweto, O. L., 1944, Preliminary report on the geology and ore deposits of the Minturn quadrangle: unpublished manuscript in open-files of U. S. Geol. Survey.

Pyrite is abundant, occurring in fissure veins, mantos in quartzite, and chimneys and mantos of copper-zinc ore in limestone; it is the principal mineral in large masses of the latter group of deposits.

12. Lovering, T. S., and Goddard, E. N., 1950, Geology and ore deposits of the Front Range, Colorado: U. S. Geological Survey Prof. Paper 223, 319 pp.

Numerous pyritic gold-quartz veins occur in most of the districts described in this comprehensive report; little quantitative data on pyrite content are given. High grade pyrite below a zinc ore shoot at the Wellington mine, Breckenridge district, was shipped for acid manufacture (pp. 119-120).

13. Ransome, F. L., 1901, The ore deposits of the Rico Mountains, Colorado: U. S. Geol. Survey 22d Ann. Rept., pt. 2, pp. 229-397.

The deposits in the Rico district are lodes, blanket veins, replacement bodies in limestone, and stocks. Pyritic ore is present in most of the lodes and in many of the blanket veins and other deposits; argentiferous galena ores form the workable deposits. Pyrite is the most abundant ore mineral and is associated with quartz and sparse chalcopyrite, sphalerite, and galena. It occurs in large blanket masses without gangue in C. H. C. Hill, and is abundant in massive replacement bodies in limestone at the Blackhawk mine. A large body of pyrite occurs in the Gold Anchor prospect in Bull Basin.

14. Vanderwilt, J. W., and others, 1947, Mineral Resources of Colorado: Colorado State Mineral Resources Board, 547 pp.

This comprehensive treatise of Colorado mineral resources is composed of three parts: Metals, nonmetals, and fuels (pt. 1); summaries of mining districts and mineral deposits, with bibliography (pt. 2); and Investigation of strategic mineral resources (pt. 3). Pyrite deposits are not separately discussed, but the principal pyrite producing districts are described: Kokomo, Climax, Gilman, and Leadville districts, and San Juan region. Pyrite is an abundant mineral in numerous deposits in these districts.

Connecticut

General - P 10

Georgia

Bell - Star mine, Cherokee County - 4
Berrong prospect, Towns County - 4; P 10
Canton (Rich) mine, Cherokee County - 4; P 10
Cash prospect, Floyd County - 4
Chestatee mine, Lumpkin County - 2, 4; P 10, 12

Dickerson prospect, Cherokee County - 4
Ivey Mount prospect, Towns County - 4
Jenny Stone prospect, Carroll County - 4; P 10
Little Bob mine, Paulding County - 4; P 10
Magruder (Seminole) mine, Lincoln County - 3, 4, 5; P 12
Marietta mine, Cobb County - 4; P 10
Number 20 mine, Fannin County - 4; Tenn. 3; P 10
Reeds Mountain mine, Carroll County - 4; P 10
Rush-Banks prospect, Paulding County - 4
Shirley mine, Paulding County - 4; P 10
Smith prospect, Cherokee County - 4
Standard mine, Cherokee County - 4, P 10
Swift (Blake) mine, Cherokee County - 4; P 10
Swift (McClarity) mine, Paulding County - 4, P 10
Tallapoosa (Waldrop) mine, Haralson County - 1, 4; P 10
Villa Rica (Sulphur) mine, Douglas County - 4; P 10

1. Ballard, T. J., and McIntosh, F. K., 1948, Diamond drilling at the Tallapoosa copper Mine, Haralson County, Ga.: U. S. Bur. Mines Rept. Inv. 4316, 8 pp.

Tallapoosa mine was worked for copper and pyrite between 1858 and 1916. Massive and disseminated sulfides, pyrite, and chalcopyrite, occur in schist in zone about 1,000 ft long. Deposit was diamond drilled in 1921. The Bureau of Mines drilled four holes in 1947.

2. Kline, M. H., and Beck, W. A., 1949, Investigation of Chestatee copper and pyrite deposit, Lumpkin County, Ga.: U. S. Bur. Mines Rept. Inv. 4397, 12 pp.

The Chestatee deposit was mined for pyrite between 1892 and 1919. Total production is unknown; recorded production between August 1918 and April 1919 was 48,835. Pyrite is the main sulfide mineral; chalcopyrite is locally rather abundant, forming ores containing 2 to 3 percent Cu. Mineralized zone is over 3,000 ft long; mica and hornblende gneiss country rock. The Bureau of Mines drilled 11 holes here in 1947.

3. Peyton, A. L., and Cofer, H. E., Jr., 1950, Magruder and Chambers copper deposits, Lincoln and Wilkes Counties, Ga.: U. S. Bur. Mines Rept. Inv. 4665, 23 pp.

Country rocks are metamorphosed volcanic rocks, now mica schist, garnet-mica schist, and amphibole-pyroxene rocks. Ore deposits are veins and stringers of chalcopyrite, sphalerite, galena, and pyrite in silicified rock. Magruder mine was first worked for gold; between 1898 and 1938 it was worked several times for copper. About 50 cars of concentrates were shipped. Production of the nearby Chambers mine is not recorded. Ten holes were drilled by the Bureau of Mines with discovery of small to moderate amounts of sulfides.

4. Shearer, H. K., and Hull, J. P. D., 1918, A preliminary report on a part of the pyrites deposits of Georgia: Georgia Geol. Survey Bull. 33, 229 pp.

This study was made during World War I, at a time when pyrite mining was very active in Georgia; the mines have all been closed since then. The deposits are mostly pyritic lenses in schist; pyrrhotite is the major sulfide in a few deposits. Minor minerals are chalcopyrite, sphalerite, and magnetite. Most of the deposits are in a belt extending northeastward across the State. The principal mines are the Reeds Mountain, Tallapoosa, Sulphur Mining and Railroad Co. (near Villa Rica), Little Bob, Shirley, Marietta, Bell-Star, Rich, Standard, Swift, and Chestatee.

5. Watson, T. L., 1904, Notes on the Seminole copper deposit of Georgia: U. S. Geol. Surv. Bull. 225, pp. 182-186.

Chalcopyrite, sphalerite, galena, and pyrite occur in three silicified zones in quartz-mica schists. Pyrite occurs as stringers in the veins, and as disseminations in the country rock. Deposit was worked for gold prior to 1884, and for copper since 1900.

Idaho

Blackbird district, Lemhi County - 3, 5,
Coeur d'Alene district, Shoshone County - 2, 4
Red Ledge mine, Adams County - 1

1. Livingston, D. C., and Laney, F. B., 1920, The copper deposits of the Seven Devils and adjacent districts: Idaho Bur. Mines and Geology Bull. 1, 105 pp.

A description of the geology and ore deposits of the district. Nearly all of the production has come from contact metamorphic deposits. The only type of deposits with appreciable pyrite are the disseminated sulfides. The Red Ledge mine, 15 miles northwest of Cuprum, has three tunnels and 1,000 ft of diamond drilling. The deposit is in a mineralized mass of rhyolite 3,000 ft wide and more than three miles long, uniformly impregnated with pyrite, with local bodies of chalcopyrite, sphalerite, galena, and other sulfides; in many places fairly large, massive bodies of pyrite occur as replacements of wall rock. Pyrite is the most abundant sulfide; gangue minerals are quartz, barite, calcite, and hematite. Some data on grade of the ore are given. The Thomas Heady prospect, a similar deposit, is briefly mentioned.

2. Ransome, F. L., and Calkins, F. C., 1908, The geology and ore deposits of the Coeur d'Alene district, Idaho: U. S. Geol. Survey Prof. Paper 62, 203 pp.

Pyrite is abundant and widely distributed in the ores. Some of the richer lead deposits have little pyrite where galena is abundant, but the ore becomes more pyritic as the galena content decreases. No large bodies of pyrite were known in the district at this time. Pyrrhotite occurs in a few deposits.

3. Reed, G. C., and Herdlick, J. A., 1947, Blackbird cobalt deposits, Lemhi County, Idaho: U. S. Bur. Mines Rept. Inv. 4012, 14 pp.

Ore bodies consist of sulfide minerals in schist and occur as pods and lenses, and as stringers and disseminations in vein zones. Ore minerals are chalcopyrite and cobaltite with pyrite and arsenopyrite. Bureau of Mines investigation consisted of trenching, drilling, and ore beneficiation tests.

4. Umpleby, J. B., and Jones, E. L., Jr., 1923, Geology and ore deposits of Shoshone County, Idaho: U. S. Geol. Survey Bull. 732, 153 pp.

Describes the disseminated deposits, the contact metamorphic replacement deposits, and the replacement deposits along fissure and fracture zones in sedimentary rocks. Most of the deposits carry galena, sphalerite, pyrite, and chalcopyrite in varying amounts in different lodes. Pyrrhotite is common in the zinc lodes. Gangue is siderite and quartz. At the Bunker Hill and Sullivan mine pyrite is widely disseminated, and is very common along the margins of ore bodies. In the lead replacement deposits in quartzite, pyrite and sphalerite occur in variable amounts; pyrrhotite and chalcopyrite are present locally. Pyrite is abundant in some lodes, sparse in others. At the Gold Hunter mine pyrite is more abundant than in the other lead-silver mines of the area, except in the Bluebird lodes of the Warner area near Kellogg.

5. Vhay, J. S., and others, 1948, Cobalt-copper deposits of the Blackbird district, Lemhi County, Idaho: U. S. Geol. Survey, Strategic Minerals Inv. Prelim. Rept. 3-219, 26 pp.

Discusses the geology and ore deposits of east-central Idaho, 20 miles southwest of Salmon. Country rocks are metamorphosed sediments cut by porphyry dikes and basic rocks. The cobalt-copper deposits are replacement deposits along shear zones; chief sulfides are pyrite, pyrrhotite, cobaltite, and chalcopyrite. Heavy sulfide masses occur in the Calera mine and the Chicago adit (largely pyrite); pyrrhotite occurs as large irregular bodies in the sulfide masses. The Bureau of Mines drilled the deposit during 1942-45. Several million tons of ore were estimated to be present.

Illinois

Coal pyrites - 1, 2, 3, 5; P 10, 14, 15
Lead-zinc district, Jo Daviess County - 4, 6, 7, 8; P 2, 7

1. Cady, G. H., 1919, Valuable pyrite in Illinois coal beds: Coal Age, vol. 16, pp. 136-140.

Pyrites occurs chiefly as balls, lenses, bands, plates, sheets, and vein fillings in coal, as nodules in fireclay, and replacements in limestone. Crystalline, brassy pyrite is generally in masses that can be readily separated from the enclosing coal; fine-grained, gray, stony pyrite, on the other hand, is commonly closely interlayered with coal. Pyrites is most abundant in the commercially important coal beds in Illinois, beds 2, 5, 6, and 7. Illinois could recover 200,000 tons of pyrites annually from coal, if pyrite were separated underground and concentrated from washery refuse; this tonnage would average about 75 percent pyrite having a sulfur content in excess of 45 percent.

2. Cady, G. H., 1922, The Illinois pyrite inventory of 1918: Illinois State Geol. Survey Bull. No. 38, pp. 427-431.

Discusses the national sulfur situation in 1918, the distribution of pyrite, its mode of occurrence, and recovery. The author states that Illinois coal mines could produce 200,000 tons of pyrite annually without additional equipment; with additional equipment the output could probably be increased to nearly 500,000 tons. Illinois produced about 24,000 tons of pyrite in 1917. The northern coals average from 3.25 to 4 percent S; in the southern counties the sulfur content ranges from 1 to 2.75 percent. Pyrite occurs as nodules or balls, as sheets or thin lenses in partings, and as lenses fingering laterally into coal. It can be recovered at the coal face and also at the tipple by pickers, or by dry or wet separation.

3. Cady, G. H., 1935, Contributions to the study of coal; distribution of sulfur in Illinois coals and its geological implication: Illinois State Geol. Survey, Rept. Inv. no. 35, pp. 23-41.

The distribution of total sulfur, and organic and pyritic sulfur in about 200 samples of Illinois coals is discussed and shown in maps and diagrams. Sulfur content of Illinois coals is usually more than 3 percent, and commonly ranges from 4 to 6 percent. Pyritic sulfur varies more widely in amount than does organic sulfur; sulfate sulfur is a minor constituent. Low organic sulfur content generally accompanies low pyritic sulfur, and vice versa. In the banded ingredients of coal, organic sulfur is usually highest in the clarain, intermediate in the vitrain, and lowest in the fusain.

4. Cox, G. H., 1914, Lead and zinc deposits of northwestern Illinois: Illinois Geol. Survey Bull. 21, 120 pp.

Includes brief notes on the occurrence of pyrite and marcasite, the production of which is very small in Illinois. Chief minerals associated with the lead and zinc ores are calcite, iron sulfide, and barite, in order of abundance.

5. Holbrook, E. A., 1917, The utilization of pyrite occurring in the Illinois bituminous coal: Univ. Illinois Bull., vol. 14, no. 51; also Eng. Exp. Sta. Circ. 5, 42 pp.

Pyrite in Illinois coals occurs as bands, lenses, nodules, and cross-cutting veinlets. Pyritic bearing coal is usually discarded in the mine or on the dump, but could be profitably recovered at some mines under current economic conditions. About 12,000 tons of pyrite were recovered from coal washing plant near Danville in 1915. The pyrite content of coal refuse at 20 plants is estimated. Experiments on concentration of pyrite are described.

6. Kenworthy, H., 1949, Metallurgical investigations of the recovery of zinc and iron sulfides from the Gray zinc-iron deposit, Galena, Ill.: U. S. Bur. Mines Rept. Inv. 4442, 12 pp.

Marcasite with minor pyrite occurs in the sphalerite ore. Sample of mill feed contained 6.64 percent Fe and 4.45 percent Zn. Metallurgical tests were run on recovery of both zinc and iron.

7. Shaw, E. W., and Trowbridge, A. C., 1916, U. S. Geol. Survey Atlas, Galena-Elizabeth, Ill.-Iowa, folio (no. 200), 13 pp.

Descriptions are included of the lead and zinc deposits occurring in the Galena dolomite and Decorah shale. Marcasite is abundant enough in some ore to be used for H_2SO_4 manufacture.

8. Willman, H. B., Reynolds, R. R., and Herbert, Paul, Jr., 1946, Geological aspects of prospecting and areas for prospecting in the zinc-lead district of northwestern Illinois: Illinois Geol. Survey Rept. Inv., no. 116.

Deposits occur in dolomite, limestone, and shale as open-fissure fillings and replacements; the bodies are usually 50-200 ft wide, from 500 ft to a mile long, and range from 5-125 ft thick. All of the ore bodies in the "lower-run" contain some iron sulfide in variable amounts. The amount of iron in the zinc ore ranges from 5-20 percent. The "middle-run" deposits overlying the "lower-run" are usually disseminated and high in iron.

Indiana

Coal pyrites - 1; P 11, 15

1. Barrett, Edward, Dove, L. P., and Holbrook, E. A., 1919, Workable coal seams of Indiana; pyrite in the coals of Indiana; The concentration of pyrite from the coals of Indiana: Indiana, Year Book, 1918, pp. 219-255.

Reports the results of the survey made in 1918 of pyrites in Indiana coals. Pyrites occurs in Indiana coals principally as bands, lenses, rounded masses, nodules, and joint veins; it is most abundant in coal seams 3, 5, and 6. Representative mines were examined, and the pyrite content of the coal and possible daily recovery of pyrite were estimated; this information is summarized in a tabular directory of the mines. Possibly 225,000 to 250,000 short tons of pyrite could be recovered annually from Indiana coal. If recovery processes using fine grinding were not utilized, recovery would be reduced to 150,000 short tons of crude material containing 50 percent or more pyrite. Results of experiments on concentration of pyrites from Indiana coals are given.

Kansas

Coal pyrites - Mo. 3; P 14

Kentucky

Coal pyrites - P 10, 14, 15

Maine

Blue Hill mine, Hancock County - 4, 6
Cape Rosier mine, Hancock County - 4, 5, 6
Douglas mine, Hancock County - 3, 4, 6
Katahdin mine, Piscataquis County - 1, 7
Tapley mine, Hancock County - 2, 4, 6

1. Bastin, E. S., 1917, Large pyrrhotite deposits in Maine: Eng. and Min. Jour., vol. 104, pp. 758-59.

Brief account of the Katahdin pyrrhotite deposit and its potential importance. Deposit is estimated to have about 100,000 long tons of ore per vertical foot, with a content of 26 to 35 percent sulfur. Deposit could be mined most cheaply by open cut. Estimates that ore could be delivered in New York area at cost of 13.3 cents per unit of sulfur.

2. Earl, K. M., 1950, Investigation of the Tapley copper deposit, Hancock County, Maine: U. S. Bur. Mines Rept. Inv. 4691, 7 pp.

The Tapley copper deposit was worked in 1880, 1907, and 1909. The deposit consists of pyrite and chalcopyrite in schistose rhyolite. Five holes were drilled by the Bureau of Mines in 1948.

3. Earl, K. M., 1950, Investigation of the Douglas copper deposit, Hancock County, Maine: U. S. Bur. Mines Rept. Inv. 4701, 17 pp.

The Douglas mine yielded between 2 and 3 million pounds of copper between 1878 and 1883; it was worked again in 1918. The deposit is a lens of sulfide minerals in mica schist; minerals are pyrite, chalcopyrite, pyrrhotite, chalcocite, arsenopyrite, sphalerite, and magnetite. Bureau of Mines drilled seven holes on strike extension of deposit, but found no new ore.

4. Emmons, W. H., 1910, Some ore deposits in Maine and the Milan mine, New Hampshire: U. S. Geol. Survey Bull. 432, 62 pp.

A general paper on the geology and ore deposits, with descriptions of mines in Hancock, Washington, Somerset, and Oxford Counties, Maine. The principal deposits are the lenticular pyritic copper deposits in schist and volcanic rocks in Hancock County. Pyrite is abundant and is accompanied by chalcopyrite, sphalerite, galena, pyrrhotite, magnetite, arsenopyrite, bornite, and chalcocite. The more important mines, all of them closed, are the Douglas, Twin Lead, Blue Hill, Stewart, Tapley, Deer Isle, Cape Rosier, and Gouldsborough. The Milan deposit in New Hampshire is similar and consists of two overlapping lenses in quartz-biotite schist. The deposit is worked from a 265-foot inclined shaft. The concentrates, containing 41.30 percent sulfur, are shipped for acid manufacture, and copper, gold, and silver are recovered from the cinder.

5. Levin, S. B., and Sanford, R. S., 1948, Investigation of the Cape Rosier zinc-copper-lead mine, Hancock County, Maine: U. S. Bur. Mines Rept. Inv. 4344, 8 pp.

Between 1881 and 1882 the Cape Rosier mine produced about 10,000 tons of ore containing about 20 percent zinc, 2.8 percent copper, and some lead. Principal ore minerals are sphalerite and chalcopyrite; pyrite is common and pyrrhotite is minor. The deposit consists of several sulfide lenses in a sheared zone in agglomeratic volcanics. In 1940-41 the St. Joseph Lead Co. drilled 13 holes here, and in 1942 an additional 9 holes were drilled by the Bureau of Mines.

6. Li, Ching-Yuan, Genesis of some ore deposits of southeastern Maine: Geol. Soc. America Bull., vol. 53, pp. 15-52, 1942.

The petrography of the country rock and mineralogy of the ores of the pyritic copper-lead-zinc deposits in southeastern Maine are described in some detail. The deposits of the Blue Hill district, and most of the other deposits, are in schist within a mile or two of granite contact, and the author concludes that the ore deposits are genetically related to the granite. The mines have been idle for some years and are inaccessible.

7. Miller, R. L., 1945, Geology of the Katahdin pyrrhotite deposit and vicinity, Piscataquis County, Maine: Maine Geol. Survey Bull. 2, 21 pp.

Slate, sandstone, phyllite, and schist are intruded by a gabbroic stock and a larger body of granite. A large pyrrhotite deposit, with surface dimensions of 2,050 ft by 400 ft, occurs in the gabbro. The ore averages 44 percent iron and 27 percent sulfur and has minor amounts of cobalt, nickel, chromium, and copper. The gossan was mined for iron ore prior to 1890. The sulfide body was drilled by the General Chemical Co. in the early 1930's. Drilling records were not available to Miller, but he believes the deposit may extend to depths of several hundred feet at least. Iron and sulfur content of the deposit would amount to 4,100,000 long tons of iron and 2,500,000 tons of sulfur for every 100 ft of depth.

Maryland

General - P 10

Massachusetts

Davis mine, Franklin County - 1, 2, 3, 4,
Hawks (Mt. Peak) mine, Franklin County - 3

1. Crosby, I. B., 1932, Report on the mineral resources of Massachusetts; a survey of the literature: Massachusetts Industry and Devel. Comm., 35 pp.

Brief note on pyrite deposits in the State. Davis mine at Rowe has been chief producer. Pyrite was mined for copper as at Hubbardston, Warcester County. Pyrite also found at Harriman mine in Boxford, Essex County.

2. Emerson, B. K., 1898, Geology of old Hampshire County, Mass.: U. S. Geol. Survey Mon. 29, p. 790.

Gives brief note on Davis pyrite mine which was 501 ft deep in 1892; production to that time was 334,552 tons of pyrite. Several small pyrite and copper prospects are mentioned.

3. Quinn, A. W., 1945, Geology of the Charlemont-Heath area (with special reference to pyrite and copper deposits): Manuscript report in open-files of U. S. Geological Survey.

Country rocks are quartzite, quartz-mica schist, graphitic schist, calcareous rocks, amphibolite, and chlorite schist. Principal deposit is the Davis pyrite mine, which was worked from 1882 to 1910. Total production to 1892 was said to have been 334,552 tons; subsequent production is not known. Deposit was mined for 900 ft along strike, and 1,400 ft down dip; its width is said to have averaged 24 ft. Pyrite is the main sulfide mineral; about 1.5 percent copper is present as chalcopyrite. Other abandoned mines in the area are the Hawks or Mt. Peak mine, and the Mary Louise or Davenport mine. Pyrite, chalcopyrite, and sphalerite are the chief minerals at the Hawks mine; it was opened to a depth of 140 ft. At the Mary Louise mine, thin veinlets of quartz and chalcopyrite occur in a mineralized zone as much as 15 ft wide.

4. Rutledge, J. J., 1906, Davis pyrites mine, Massachusetts: Eng. and Min. Jour., vol. 82, pp. 673-676, 724-727, 772-774.

Davis pyrite mine in Franklin County was opened in 1882 and has been worked continuously since then. Deposit is a pyritic lens in mica and quartz schists; some chalcopyrite and sphalerite are present. The lens has been opened for a length of 450 ft along the strike and about 1,200 ft down dip; it is 30 to 40 ft thick on the no. 1 level. Most of article is devoted to discussion of mining and milling practices. Production is about 3,000 long tons monthly, of which 70 percent is lump ore and the rest fines. Average sulfur content is 47 percent and copper content about 1.5 percent.

Michigan

Iron River district, Iron County - 1

1. James, H. L., 1951, Iron formation and associated rocks in the Iron River district, Michigan: Geol. Soc. America Bull., vol. 62, pp. 251-266.

A petrographic description and discussion of the origin of the iron formation and associated rocks in the Iron River district. The iron formation consists mainly of interlayered chert and siderite where unoxidized. It is underlain by a highly pyritic graphite slate that ranges from 20 to 50 ft in thickness. The pyrite makes up 35 to 40 percent of the rock, but is rarely visible because of its extremely fine grain. The average iron content of the pyritic slate is about 20 percent, the iron formation about 25 percent, and overlying beds of magnetic ironstone about 20 percent. The iron is believed to have been deposited under sedimentary conditions, and to have been derived from adjacent land masses during favorable climatic conditions. Iron sulfide was deposited in basins having poor bottom circulation and containing abundant H_2S and organic matter.

Minnesota

Long Lake region, Crow Wing County - 1, 2

1. Emmons, W. H., and Grout, F. F., 1943, Mineral resources of Minnesota: Minnesota Geol. Survey Bull. 30, p. 132.

Brief mention that iron sulfides occur in a belt near the Cuyuna iron range (12 miles southeast of Atkin), and are also known in the Vermilion and Gunflint districts.

2. Thiel, G. A., 1924, Iron sulphides in magnetic belts near the Cuyuna range: Econ. Geology, vol. 19, pp. 466-472.

Brief notes on occurrences of pyrrhotite, pyrite, and marcasite in the schists and slates intruded by igneous rocks in the Long Lake region, Minnesota. Deposits are replacements in sediments, and sulfides are locally massive. Pyrrhotite is especially abundant near basic sills, some drill cores consisting of over 50 percent sulfide. A 12-foot section consisting of 7 ft of iron formation and 5 ft of gabbro averaged 14 percent pyrrhotite. The deposits are apparently disseminated and small in size.

Mississippi

General - P 10

Missouri

Coal pyrites - 2, 3, 4
Buckland mine, Phelps County - 3, 5
Cherry Valley mines, Crawford County - 3, 5
Clay mine, Madison County - 3
Cook prospect, Washington County - 3, 5
Copper mine, Maries County - 3
De Lore mine, Jefferson County - 3, 5
Duckworth mine, Franklin County - 1, 3, 5
Flat Rock mine, Phelps County - 3, 5
Fredericktown mines, Madison County - 3
Hinote prospect, Wright County - 3
Hobo mine, Crawford County - 3, 5
Kelsey mine, Franklin County - 3, 5,
Lambert prospect, Miller County - 3
Laswell mine, Howell County - 3
Leslie mine, Franklin County - 3, 5
Moselle no. 10 mine, Phelps County - 3, 5
Pioneer no. 2 prospect, Miller County - 3
Rueppele mine, Franklin County - 3, 5
St. Clair mine, Franklin County - 3, 5
Starkey mine, Madison County - 3

1. Dupuy, L. W., and Ballinger, H. J., 1949, Filled-sink iron deposits in Crawford, Dent, Franklin, and Texas Counties, Mo., U. S. Bur. Mines Rept. Inv. 4452, 23 pp.

Hematitic filled-sink deposits in the Central Ozarks were explored on seven properties by churn-drill holes. At the Duckworth pyrite mine iron sulfides were intersected over a length of 27 ft in the bottom of one hole beneath hematite.

2. Gallagher, R. T., 1940, Mineral content of the Review coal seam, Boone County, Mo.: Mines Mag., vol. 30, pp. 586-590, 611-612.

Pyrite is one of the dominant minerals in the Bevier coal seam, occuring as bands, lenticular masses, vertical seams, and disseminations. Marcasite or pyrite, or both, with some clay form a persistent layer about 10 in. from the roof of the coal bed; this type of iron sulfide is believed to have formed syngenetically with the coal. Lenticular masses of pyrite seem to be replacements of carbonate concretions. Joint veins of pyrite, sphalerite, calcite, and gypsum are later than the coal in origin.

3. Grawe, O. R., 1945, Pyrites deposits of Missouri: Missouri Geol. Survey and Water Resources, vol. 30, ser. 2, 447 pp.

Discusses the mining history, production, deposits, mineralogy, and origin of the sink structures, and describes the mines and prospects. Pyrites districts are as follows: northwestern part of State associated with coal; northern part of Ozark uplift associated with hematite-bearing sink structures in limestone; at or near the contact of dolomite with igneous rocks in Madison County, associated with limonite deposits and with sphalerite-bearing fractures in Howell County; in fault zones with barite, galena, and sphalerite in Jefferson and Washington Counties, and in fractures and cavities in dolomite in Wright County. Pyrite and marcasite are abundant in the sink structures and this source is the only area where marcasite has been mined for its sulfur content. The deposits were reopened in 1932 and mining continued until 1940. From 1911 to 1940 Missouri produced 251,125 tons of pyrites.

4. Mathias, H. E., 1928, Syngenetic origin of pyrite concretions in the Pennsylvania shales of north-central Missouri: Jour. Geology, vol. 36, pp. 440-450.

Pyrite concretions are common in a bed of marine shale, about 4 ft thick, that lies immediately above the Bevier coal. Concludes that concretions are of syngenetic origin.

5. Tarr, W. A., 1937, Origin of the marcasite sink-hole deposits of central Missouri: Am. Mineralogist, vol. 22, pp. 830-841.

Ten marcasite sink-hole deposits are known in northeastern Ozarks. Marcasite occurs in elliptical or irregular sink-holes in Ordovician rocks; believes marcasite was deposited from magmatic waters in late Cretaceous time. The iron sulfides are overlain by hematite that was formed by weathering. Two mines were operating in 1936.

Montana

Butte mines, Silver Bow County - 5, 6, 7, 8
Golden Curry (Elkhorn) mine, Jefferson County - 2
Keystone mine, Broadwater County - 3
Mouat nickel mine, Stillwater County - 1, 4

1. Howland, A. L., Peoples, J. W., and Sampson, Edward, 1936, The Stillwater igneous complex and associated occurrences of nickel and platinum groups of metals: Montana Bur. Mines and Geology, Misc. Contr. no. 7, 15 pp.

Massive sulfide bodies and disseminated sulfides occur in chilled norite at the base of the Stillwater complex and in the underlying hornfels. The principal sulfide is pyrrhotite, which is accompanied by chalcopyrite and pentlandite.

2. Knopf, Adolph, 1913, A magmatic sulphide ore body at Elkhorn, Mont.: Econ. Geology, vol. 8, pp. 323-336.

At the Golden Curry mine, pyrrhotite occurs with augite and minor chalcopyrite in an ore body in quartz monzonite. Deposit is 100 ft long, as much as 18 ft wide, and has been mined to a depth of 10 or 12 ft. Deposit is regarded as a magmatic segregation in origin.

3. Pardee, J. T., and Schrader, F. C., 1933, Metalliferous deposits of the greater Helena mining region, Montana: U. S. Geol. Survey Bull. 842, 311 pp.

Principal pyritic deposit in the region is the Keystone mine in the Radersburg or Cedar Plains district. This mine has been the most productive in the district; it is developed to a depth of 550 ft and 1,000-2,000 ft along the vein from a shaft. Most of the ore is massive, auriferous pyrite; with local gangue of quartz and calcite.

4. Roby, R. N., 1949, Investigation of copper-nickel deposits of the Stillwater complex, Stillwater and Sweetgrass Counties, Mont.: U. S. Bur. Mines Rept. Inv. 4431, 10 pp.

Bodies of copper-nickel-iron sulfides occur at the base of the Stillwater complex of basic igneous rocks. Sulfides are pyrrhotite, chalcopyrite, pentlandite, and minor pyrite. Nickel content averages about 0.42 percent, copper about 0.37 percent. One lot of higher grade ore contained 20.3 percent sulfur. Eight holes were drilled by Bureau of Mines at the Mouat deposit. Individual pods and lenses are estimated to contain from 1,000 to more than 1,000,000 tons of sulfide-bearing material.

5. Sales, R. N., 1914, Ore deposits at Butte, Mont.: Am. Inst. Min. Eng. Trans., vol. 46, pp. 3-106.

Describes the structure, rock and vein alteration, ore deposits, vein systems, and genesis. Pyrite is the most widely distributed of the sulfides and occurs both massive and crystalline in veins and fissures, as well as abundantly disseminated in altered granite. It is more abundant in the early copper veins of the Anaconda system than in the later veins, and much more abundant in the central copper veins than in the Mn-Ag veins of the peripheral areas. Sales doubts if there is any change in total pyrite present between the upper and deep levels of the mines. In the central zone chalcocite and enargite predominate in a gangue of quartz and pyrite. In the intermediate zone in veins of the Anaconda system pyrite and quartz are very abundant locally. In the peripheral zone pyrite is common, but in much less amounts than in the other two zones.

6. Sales, R. H., and Meyer, Charles, 1948, Wall rock alteration at Butte, Mont.: Am. Inst. Min. Met. Eng., Tech. Pub. 2400, 25 pp.

Zones of sericitized quartz monzonite along the veinward edge and argillized monzonite along the outer edge occur adjacent to every ore-bearing fracture in the district. More intense sericitization in the central zone has eliminated the lower grade alteration products. Minerals of the sericite zone in decreasing order of abundance are sericite, quartz, and pyrite. Widths of alteration zones increase with depth. Proceding into the central zone along the major vein systems, chemical gains in silica, alumina, potash, iron, and much sulfur in the sericitized zone exceed losses of the same in argillized zone. Cross-sections showing veins, alteration zones, and chemical changes indicate a pyrite content of about 4 to 12 percent in the sericitized zones along the veins.

7. Sales, R. H., and Meyer, Charles, 1949, Results from preliminary studies of vein formation at Butte, Mont.: Econ. Geology, vol. 44, pp. 465-484.

Replacement of wall rock by hypogene sulfides appears to have been the dominant process in vein growth. Quartz and pyrite, the most stable minerals of the vein channels, are the common vein framework and are often accompanied by chalcocite and enargite in the central zone, sphalerite in the intermediate zone, and rhodochrosite in the peripheral zone. The peripheral zone is characterized by much less pyrite than in the deeper copper zones. Chalcocite with bornite and pyrite are characteristic of the central zone of complete sericitization.

8. Weed, W. H., 1912, Geology and ore deposits of the Butte mining district, Mont.: U. S. Geol. Survey Prof. Paper 74, 262 pp.

Pyrite is second to quartz in abundance as a constituent of the copper veins and is common in altered granite adjacent to the veins; also forms massive pyrite veinlets in the oldest mineralized fissures which carry some Cu. Marcasite is common and occurs admixed with pyrite and in vugs. In the highly altered quartz monzonite disseminated pyrite is abundant together with sericite and quartz; its formation is an important feature of the monzonite alteration. Fresh monzonite carries .04-.07 percent pyrite; the altered rock 4-6 percent pyrite, which was partly derived from magnetite and alteration of ferromagnesian minerals. Vein material is largely the result of replacement.

Nevada

Copper Canyon mine, Lander County - 5
Ely mines, White Pine County - 1, 4
Mt. Hope mine, Eureka County - 3
Pioche district, Lincoln County - 6
Yerington district, Lyon County - 2

1. Bateman, A. M., 1935, The copper deposits of Ely, Nev., in Copper resources of the world: Inter. Geol. Cong., 16th sess., Washington, pp. 307-321, 1935.

Describes the geology and copper deposits of Ely, Nev. Pyrite and chalcopyrite are principal hypogene sulfide minerals in the disseminated "porphyry" copper deposits and higher grade deposits in limestone. Porphyry ores contain 9 to 10 percent sulfides, of which about half is pyrite.

2. Knopf, Adolph, 1918, Geology and ore deposits of the Yerington district, Nevada: U. S. Geol. Survey Prof. Paper 114, 68 pp.

Deposits are of contact metamorphic type, and consist of chalcopyrite and pyrite in a gangue of silicates. Average tenor of ore mined is from 2.75 to 6 percent copper. Relative amount of sulfides varies widely in different deposits; mines carrying appreciable pyrite are the Mason Valley mine and the Ludwig mine. Pyrite is twice as abundant as chalcopyrite at the Mason Valley mine. In the Ludwig mine the garnetiferous quartz-pyrite ore grades into a heavy pyrite ore toward the footwall; large pyritic masses also occur.

3. Matson, E. J., 1946, Exploration of the Mount Hope mine, Eureka County, Nev.: U. S. Bur. Mines Rept. Inv. 3928, 7 pp.

Ore bodies at Mount Hope mine are replacement deposits in altered limestone roof pendants in alaskite stock. Marmatite is the chief ore mineral and is accompanied by galena, chalcopyrite, and pyrrhotite. Eighteen holes were drilled by the Bureau of Mines. Ore bodies are irregular; pyrrhotite was found near the igneous contact in several holes.

4. Spencer, A. C., 1917, Geology and ore deposits of Ely, Nev.: U. S. Geol. Survey Prof. Paper 96, 189 pp.

Porphyry copper deposits at Ely carry pyrite, minor chalcopyrite, and secondary chalcocite; a large tonnage of ore carries about 3 percent sulfur in the form of primary sulfides, mostly pyrite. Sulfide vein and replacement deposits, some with abundant pyrite, also occur in metamorphosed limestones and shales. Two large irregular replacement bodies of pyrite have been found beneath gossan. Pyrite is the most abundant and widely distributed metallic mineral, and is estimated to constitute 4 to 8 percent by weight of the metamorphosed rocks.

5. Trengrove, R. R., 1951, Investigation of Copper Canyon lead-zinc deposit, Lander County, Nev.: U. S. Bur. Mines Rept. Inv. 4774, 61 pp.

Copper and lead-zinc ore bodies at Copper Canyon are veins and disseminated deposits. Pyrite and pyrrhotite occur in both types of ore-bodies. The Bureau of Mines drilled 18 holes from underground workings to explore the lead-zinc body.

6. Westgate, L. G., and Knopf, Adolph, 1932, Geology and ore deposits of the Pioche district, Nevada: U. S. Geol. Survey Prof. Paper 171, 79 pp.

Combined Metals Reduction Co.'s mine at Pioche is in a replacement deposit of practically massive intergrowth of pyrite, sphalerite, and galena. The ore body is a tabular mass 30-40 ft thick at the intersection of a steep fissure and a flat-dipping limestone bed in Pioche shale. Pyrite comprises 60 percent, sphalerite 22 percent, and galena 8 percent of the ore; chalcopyrite is uncommon, and gangue is sparse. The periphery of the ore body is higher in pyrite.

New Hampshire

Croydon mine, Sullivan County - 3
Gardner Mountain district, Grafton County - 3, 4; P 12
Milan mine, Coos County - 1, 3; Me 4; P 4, 10, 12, 13
Neal mine, Sullivan County - 3; P 10
Ore Hill (Warren) mine, Grafton County - 2, P 12

1. Earl, K. M., 1950, Investigation of Milan copper deposit, Coos County, N. H.: U. S. Bur. Mines Rept. Inv. 4718, 9 pp.

The Milan deposit was worked at several different periods between the 1870's and 1910. Principal minerals are pyrite, chalcopyrite, and sphalerite, which form a lenticular deposit in schist. Bureau of Mines drilled eight holes.

2. Hermance, H. P., and Mosier, McHenry, 1948, Investigations of the Ore Hill zinc-lead mine, Grafton County, N. H.: U. S. Bur. Mines Rept. Inv. 4328, 13 pp.

Ore Hill mine near Warren was worked from before 1869 to 1914. The deposit is a lenticular sulfide body in schist; principal minerals are sphalerite and galena, with some pyrite and chalcopyrite. The Bureau of Mines drilled 14 holes and unwatered and sampled upper mine workings.

3. Hitchcock, C. H., 1878, Economic geology (of New Hampshire): Geology of New Hampshire, vol. 3, pt. 5, pp. 35-52.

Copper deposits on Gardners Mountain, Grafton County, are made up of chalcopyrite, pyrite, pyrrhotite, and quartz, with some sphalerite and galena. Five mines have been opened. The Milan and Warren mines are described briefly. Deposits that may have potential value as pyrites mines are the Croydon and Neal mines in Sullivan County. At the Croydon mine, chalcopyrite, and pyrrhotite are in a vein 6 ft thick; the Neal vein is 3 ft thick and 2,200 ft long.

4. Ross, C. P., 1923, The geology of a part of the Ammonoosuc mining district, New Hampshire: Am. Jour. Sci., 5th ser., vol. 5, pp. 267-302.

Geology of an area of metamorphic rocks in western New Hampshire is described. Pyrite-chalcopyrite deposits are mentioned briefly; Granite State mine is only one of importance.

New Jersey

Cooper mine, Morris County - 1
Hackelbarney mine, Morris County - 1; P 10
Pochuck deposit, Sussex County - 4; P 10
Silver mine, Sussex County - 1
Sulphur Hill (Andover) mine, Sussex County - 1, 2
Washington mine, Warren County - 1, 3

1. Bayley, W. S., 1910, Iron mines and mining in New Jersey: New Jersey Geol. Survey. Final Rept. Ser., vol. 7, 512 pp.

A comprehensive treatise on the geology of the iron districts, and the mining operations. Principal deposits are the magnetite bodies in pre-Cambrian gneisses in the Highlands of northern New Jersey. Pyrite, and occasionally pyrrhotite, are common in some ores and had to be removed by roasting. Analyses of ores from 19 mines contain more than 2 percent sulfur. The principal magnetite deposits with appreciable pyrite seem to be Sulphur Hill, Cooper, Hackelbarney, and Washington mines. Pyrrhotite and pyrite predominate at the Silver mine.

2. Lynch, V. J., 1947, Andover-Sulphur Hill iron mine, Sussex County, N. J.: U. S. Bur. Mines Rept. Inv. 4152, 12 pp.

Magnetite with sphalerite, chalcopyrite, and pyrite occurs in lenticular bodies in gneiss. Dip needle survey was made at Sulphur Hill mine. Two holes were drilled at Andover mine, and four at Sulphur Hill mine.

3. Smith, L. L., 1933, Magnetite ores of northern New Jersey: Econ. Geology, vol. 28, pp. 658-677.

Gives summary of the geology and structure of the pre-Cambrian gneisses of the New Jersey Highlands. The lenticular magnetite deposit of the Washington mine is described and its origin discussed. Ore contains pyrite, and locally a little pyrrhotite. Ore previously mined contained as much as 4 percent sulfur, but content is lower now. Pyrite is said to occur also in the disseminated magnetite deposit of the Scrub Oaks mine.

4. Spencer, A. C., and others, 1908, U. S. Geol. Survey Geol. Atlas, Franklin Furnace, N. J., folio (no. 161), p. 23.

The limonite deposit at the Pochuck mine lies along fault contact between Paleozoic limestone and pre-Cambrian limestone. Limonite pseudomorphs after pyrite occur; author thinks deposit may be gossan of pyrite deposit.

New Mexico

Central district, Grant County - 2, 4, 5, 6, 8, 9, 10
Magdalena district, Socorro County - 4, 6, 7
Pecos mine, San Miguel County - 1, 3, 4

1. Harley, G. T., 1940, The geology and ore deposits of northeastern New Mexico (exclusive of Colfax County): New Mexico [School of Mines] Bull. 15, 104 pp.

Principal mine in area is Pecos lead-zinc mine, which was closed in 1939 after producing 2,000,000 tons of ore. Deposit is massive sulfide body in schist with sphalerite, galena, a little chalcopyrite, and much pyrite.

2. Kelley, V. C., 1949, Geology and economics of New Mexico iron-ore deposits: Univ. New Mexico Pub. in Geology No. 2, 246 pp.

Pyrite occurs in appreciable amounts in some contact pyrometasomatic magnetite deposits. Some ores will be of little value unless processes are used to remove the pyrite. Considerable pyrite is contained in the large ore reserves of the Fierro-Hanover districts.

3. Krieger, Philip, 1932, Geology of the zinc-lead deposit at Pecos, N. Mex.: Econ. Geology, vol. 27, pp. 344-364; 450-470.

Lenticular massive sulfide bodies occur in a broad shear zone in pre-Cambrian diabase and granite; these rocks are covered in much of the area by limestone, sandstone, and arkose of Pennsylvanian age. The ore bodies, ranging from 2 to 50 ft in width, occur in quartz-sericite schist and quartz-chlorite schist, believed to represent respectively sheared granite and sheared diabase or mixed diabase and granite. Pyrite and sphalerite are the most abundant sulfides; galena, chalcopyrite, and pyrrhotite occur in subordinate amounts, and bornite is rather scarce. During a 3-year period, the American Metal Co. has produced 584,158 tons of ore with an average content of 16.06 percent Zn, 3.73 percent Pb, 1.02 percent Cu, 3.39 oz. Ag and 0.109 oz. Au per ton.

4. Lasky, S. G., and Wootton, T. P., 1933, The metal resources of New Mexico and their economic features: New Mexico [School of Mines] Bull. 7, 178 pp.

Metal mines and districts are listed where pyrite and pyrrhotite occur, and the various districts are described.

5. Lasky, S. G., 1936, Geology and ore deposits of the Bayard area, Central mining district, New Mexico: U. S. Geol. Survey Bull. 870, 144 pp.

A detailed geologic study of about 8.75 sq mi in the Central district, New. Mexico. Most of the production of the area has come from the Ground Hog and Lucky Bill mines, which are on the same vein. Galena and sphalerite are the most abundant ore minerals, and are accompanied by small amounts of chalcopyrite; some silver and gold are recovered. Pyrite is very common and is the predominant sulfide in places.

6. Lingren, Waldemar, Graton, L. C., and Gordon, C. H., 1910, The ore deposits of New Mexico: U. S. Geological Survey Prof. Paper 68, 361 pp.

This comprehensive treatise on the ore deposits of the State mentions pyrite under the descriptions of individual mines, but does not discuss the resources of pyrite.

7. Loughlin, G. F., and Koschmann, A. H., 1942, Geology and ore deposits of the Magdalena mining district, New Mexico: U. S. Geol. Survey Prof. Paper 200, 168 pp.

There are some pyrite masses present which would be a small reserve for the manufacture of sulfuric acid. Massive pyrite has replaced part of the limestone in the Nitt mine and the north end of the main ore shoot in the Graphic-Waldo mine; it carries very low Ag and Au values. Pyritic ore occurs along base of sulfide zone of the Graphic-Waldo mine where it carries enough chalcopyrite to be of ore grade. Pyrite is the chief sulfide along the eastern part of the main ore zone in the Nitt and Graphic-Waldo mines; it also forms lenses and layers in specularite-magnetite masses.

8. Paige, Sidney, 1916, U. S. Geol. Survey Geol. Atlas, Silver City, N. Mex. folio (no. 199), 19 pp.

Includes a geologic map of the 30-minute quadrangle, and brief descriptions of mineral deposits in Hanover, Fierro, Santa Rita, Burro Mountains, Pinos Altos, and other localities.

9. Schmitt, Harrison, 1933, The Central mining district, New Mexico: Am. Inst. Min. Met. Eng., Contrib. no. 39, 22 pp.

The iron, zinc, and copper deposits surrounding the quartz-monzonite porphyry stocks of the Central mining district are described. Pyrite is an abundant mineral.

10. Schmitt, Harrison, 1939, The Pewabic mine: Geol. Soc. America Bull. 50, pp. 777-818.

The Pewabic zinc deposit, Hanover, N. Mex., is in a zone of contact pyrometasomatism around a quartz monzonite body. Pyrrhotite is abundant in part of the deposit; pyrite is present in lesser amounts.

New York

Anna mine, St. Lawrence County - 3, 12, 15, 16, 17
Balmat mine, St. Lawrence County - 2, 6; P 7
Clove mine, Orange County - 4
Cole mine, St. Lawrence County - 1, 3, 12, 15, 16, 17
Croft mine, Putnam County - 4, 18
Croton (Brewster or Theall) mine, Westchester County - 4, 7, 9
Edwards mine, St. Lawrence County - 6, 14, 19
Phillips (Anthonys Nose) mine, Westchester County - 10, 16; Pa. 5
Pyrites (High Falls) mine, St. Lawrence County - 1, 3, 5, 12, 13, 15, 16, 17
Red-back mine, Orange County - 4, 8, 11
Standish (Warwick) mine, Orange County - 4
Stella mine, St. Lawrence County - 1, 3, 5, 12, 13, 15, 16, 17

1. Brinsmade, R. B., 1905, Pyrite mining in St. Lawrence County, N. Y.: Eng. and Min. Jour., vol. 80, pp. 770-771.

Describes deposits, and mining and milling operations at the Cole, Stella, and High Falls mines. The ore at the Cole mine contains 20 to 30 percent sulfur; the jig concentrates carry 40 to 50 percent sulfur.

2. Brown, J. S., 1936, Structure and primary mineralization of the zinc mine at Balmat, N. Y.: Econ. Geology, vol. 31, pp. 233-258.

Country rocks are gneisses and limestones intruded by gabbro, syenite, and granite. Ore shoots are sulfide replacements along banding; the chief sulfides are sphalerite and pyrite. Pyrite is irregularly distributed and some shoots are highly pyritic with little sphalerite. The three types of ore are: highly pyritic ore with silicious gangue, rich sphalerite ore low in pyrite, and intermediate type in which both sulfides are abundant. Minor galena is present. Compares the ores with those of Hyatt, which carries less pyrite, and of Edwards which contains the lowest percentage; chemical and mineralogical analyses of ores from these three deposits are given. Production began in 1930, and by 1935 averaged 700 tons of ore daily that yielded 100 tons of zinc concentrates and 125 tons of pyrite concentrates.

3. Buddington, A. F., 1917, Report on the pyrite and pyrrhotite veins in Jefferson and St. Lawrence Counties, N. Y.: New York State Defense Council, Bull. 1, 40 pp.

Pyrite and pyrrhotite deposits occur in seven belts, of which five belts form a northeasterly trending zone, 40 miles long, and 3-4 miles wide. Deposits consist of veins and rich disseminations of iron sulfides in chloritized zones in injection gneisses. Some deposits are as much as half a mile in length, and as much as 25 ft in thickness; the Stella vein was mined 900 ft down dip without any change in character. Ore averages about 20 percent sulfur and is concentrated to 40 percent. Principal mines have been the Stella, Pyrites, and Cole mines; 15 other mines, prospects, and deposits are described.

4. Colony, R. J., 1923, The magnetite iron deposits of southeastern New York: New York State Museum Bull. nos. 249-250, 161 pp.

The magnetite deposits, and the geology and petrography of the pre-Cambrian rocks of southeastern New York are described and discussed. Several percent sulfur in the form of pyrite or pyrrhotite occur in the ores of the following mines: Red-back, Hogencamp, Standish (or Warwick), and Clove mines, Orange County; Croft mine, Putnam County; and Croton, Brewster (or Theall) mine, Westchester County.

5. Eckel, E. C., 1905, Pyrite deposits of the western Adirondacks, New York: U. S. Geol. Survey Bull. 260, pp. 587-588.

Brief notes on pyrite deposits and current mining operations at Stella and at Pyrites or High Falls mines, St. Lawrence County.

6. Hermance, H. P., and Sanford, R. S., 1949, Investigation of Parker and Webb zinc deposits, St. Lawrence County, N. Y.: U. S. Bur. Mines Rept. Inv. 4417, 31 pp.

The Parker property is about a mile from the Balmat mine, and the Webb property about 2 miles from Edwards. The Bureau of Mines drilled six holes at the Parker property and five holes at the Webb deposit. Considerable pyrite and graphite were found in one hole at the Parker deposit; sphalerite and pyrite were found in holes previously drilled.

7. Hoffman, W. H., 1893, The late discovery of large quantities of magnetic and non-magnetic pyrites in the Croton magnetic iron mines: Am. Inst. Min. Eng. Trans., vol. 21, pp. 513-515.

Note on the occurrence of unusually large amounts of pyrite and pyrrhotite in the Theall tunnel of the Croton magnetite mine. This type of ore carries 6 to 10 percent sulfur, and locally more than 20 percent. Ore normally contains several percent sulfur, which is removed by roasting.

8. Hotz, P. E., 1945, Preliminary report on the geology of the Sterling-Ringwood magnetite district, New York and New Jersey: Mimeographed report in open-files of U. S. Geol. Survey, 6 pp., 2 maps.

Summary account of geology and magnetite deposits of New York-New Jersey Highland area, with suggested aids to exploration, and preliminary geologic map. Magnetite deposits have some iron sulfides and chalcopyrite, and are conformable to gneissic foliation. The subject will be covered more fully by author's paper entitled, Magnetite deposits of New Jersey and New York Highlands, U. S. Geol. Survey Bull. 982-, (in press).

9. Koeberlin, F. R., 1909, The Brewster iron-bearing district of New York: Econ. Geology, vol. 4, pp. 713-54.

Describes geology of the area, petrography, and the magnetite deposits. Brief mention of occurrence of pyrrhotite and pyrite at the Croton mine.

10. Loveman, M. H., 1911, Geology of the Phillips pyrites mine near Peekskill, N. Y.: Econ. Geology, vol. 6, pp. 231-246.

The paper is mainly a description of the rock types of the region and the mine, and a theoretical discussion of the origin of the deposit. Country rocks are various types of pre-Cambrian igneous and sedimentary gneisses. Ore is mostly pyrrhotite, with smaller amounts of pyrite, magnetite, and chalcopyrite. Maximum thickness of deposit is about 25 ft; it has been mined for several hundred feet along the strike and a hundred feet down dip. Ore was burned for H_2SO_4 manufacture.

11. Millar, W. T., Hammond, H. O., and Sanford, R. S., 1949, Investigation of Red-Back magnetite mine, Sterling Lake, Orange County, N. Y.: U. S. Bur. Mines Rept. Inv. 4469, 4 pp.

The mine was last worked in 1880, and abandoned presumably because of high sulfur content. Magnetite is accompanied by pyrite, pyrrhotite, and chalcopyrite. Seven holes were drilled by the Bureau of Mines; assays are given for iron but not sulfur.

12. Miller, W. J., 1926, Origin of pyrite deposits of St. Lawrence County, N. Y.: Econ. Geology, vol. 21, pp. 65-67.

Pyrite deposits occur in two belts of Grenville gneisses that are injected and soaked by granite and pegmatitic granite. Ore bodies are as much as 20 ft thick and have average content of 20 percent sulfur. Concludes that pyrite was an original constituent of the gneisses, and has been transported and redeposited by liquids and vapors associated with the granite and pegmatite.

13. Newland, D. H., 1907, The mining and quarry Industry of New York: New York State Mus. Bull. 120, pp. 50-52.

A brief description of the mining operations and geology at Stellaville, Gouverneur, and Pyrites in St. Lawrence County. The pyrite at the Stella mine is free of arsenic and was shipped to acid plants.

14. Newland, D. H., 1917, The zinc-pyrite deposits of the Edwards district, New York: New York State Defense Council Bull. 2, 72 pp.

The deposits are in southern St. Lawrence County near Edwards, and occur in limestone. Sulfides are sphalerite and pyrite; the proportion of pyrite is usually low even in the highest grade ore. An analysis of an average sample from the Northern Ore Co.'s mine at Edwards gave 60.61 percent Zn, 4.91 percent Fe, and 32.73 percent S. The only production in the district has come from this mine. The first shipments of zinc ore and pyrite were made in 1915.

15. Newland, D. H., 1917, Pyrite in northern New York: Eng. and Min. Jour., vol. 104, pp. 947-948.

A summary of the pyrite deposits in St. Lawrence and Jefferson Counties, N. Y. Lenses of pyritized schist and quartzite, carrying about 20 percent S, occur in a zone 40 miles long. Ore has been mined from two belts, the Stella-Pyrites and Richville. The lean ore is concentrated by jigs and tables to a product containing 45 percent sulfur. Believes that production could be expanded considerably to supply annually 250,000 tons of concentrates containing 40 to 45 percent sulfur at a cost of about 10 cents per unit of sulfur.

16. Newland, D. H., 1921, The mineral resources of the State of New York: New York State Museum Bull. nos. 223-224, 315 pp.

Gives summary of the following occurrences of pyrite (pp. 209-218): pyrite deposits in gneiss, St. Lawrence and Jefferson Counties; pyrite in graphite ores, Essex, Warren, and Washington Counties; pyrrhotite deposit at Anthony's Nose; and pyrite nodules in shales near Schoharie.

17. Smyth, C. H., 1912, On the genesis of the pyrite deposits of St. Lawrence County: New York State Mus. Bull. 158, pp. 143-182.

The pyrite deposits occur in crystalline limestones, gneisses, schists, and quartzites cut by granitic rocks. The ore body at the Cole mine is about 10 ft thick, and the pyrite occurs in streaks, bunches, and veins associated with graphite. The Hendricks, Styles, and Farr mines are prospects in bands of rusty gneiss. The Stella mines have the largest workings of the area; pyrite with considerable pyrrhotite is mined in two zones of gneiss each underlain by hornblende gneiss. At the Stella mine the ore body is 10 ft wide, 1100 ft long, and 900 ft down the dip; the ore body at the Anna mine is 20 ft thick, 1200 ft long, and 250 ft down the dip. The mines at Pyrites or High Falls are in two ore lenses in gneiss underlain by gabbro.

18. Stewart, C. A., 1908, The magnetite belts of Putnam County, N. Y.: School of Mines Quarterly, vol. 29, pp. 283-294.

Brief discussion of the magnetite deposits and the petrography of the ores and country rock. Considerable pyrite occurs at the Croft mine.

19. Wade, W. R., and Wandke, Alfred, 1923, A big zinc mine in New York State: Eng. and Min. Jour., vol. 116, pp. 95-99.

Deposits at Edwards consist of lenticular bodies of sphalerite and pyrite in folded Grenville limestone. Mining and milling methods are described; products are zinc concentrates and pyrite concentrates.

No. Carolina

Big Ore Bank mine, Lincoln County - 2
Crouse (Oliver or Pasour) mine, Gaston County - 7; P 10.
Cullowhee mine, Jackson County - P 9, 12
Elk Knob prospect, Watauga County - 5; P 9, 10, 12
Fontana mine, Swain County - P 9
Ore Knob mine, Ashe County - 1, 3, 4, 6; P 9, 10, 12, 13
Otto (Macon or Cabes) prospect, Macon County - P 9, 10
Savannah mine, Jackson County - P 9

1. Ballard, T. J., and Clayton, A. B., 1948, Investigation of the Ore Knob copper mine, Ashe County, N. C.: U. S. Bur. Mines Rept. Inv. 4341, 8 pp.

Ore Knob mine was worked for copper periodically between 1860 and 1927. The main period of operation was between 1873 and 1883, when nearly 25,000,000 pounds of copper was produced from over 200,000 tons of ore. The ore is mostly pyrrhotite with some pyrite and chalcopyrite, and minor sphalerite, in a mineralized zone over 1,800 ft long in biotitic gneiss. The Bureau of Mines drilled 20 holes and drove 75 ft of drifts and cross cuts in 1942-43.

2. Clayton, A. B., and Montgomery, W. B., Jr., 1948, Diamond drilling at the Big Ore Bank magnetite deposits, Lincoln County, N. C.: U. S. Bur. Mines Rept. Inv. 4347, 6 pp.

The deposits were worked for magnetic iron ore following the Civil War. Magnetite with some iron sulfides occurs in lenticular bodies in schists in a zone nearly a mile long. Magnetic survey was made by the North Carolina Geological Survey. The Bureau of Mines drilled 10 holes in 1943-44. Composite samples from several drill holes contain about 5 percent sulfur.

3. Egleston, Thomas, 1881, Investigations on the Ore Knob copper process: Am. Inst. Min. Eng. Trans., vol. 10, pp. 25-57

Report is primarily a detailed account of the roasting and smelting practices at Ore Knob, with some brief notes on mining and geology. Primary sulfide ores containing 3 percent copper or better are being mined; lower grade ores are not touched.

4. Hunt, T. S., 1873-74, The Ore Knob copper mine and some related deposits: Am. Inst. Min. Eng. Trans., vol. 2, pp. 123-129.

Describes the gossan, secondary copper zone, and underlying primary pyrrhotite-chalcopyrite ore at Ore Knob, N. C. Mine workings had been recently opened over a distance of 661 ft in the copper ores. Discusses similar pyrrhotite deposits at Ducktown, Tenn., and Carroll, Floyd, and Grayson Counties, Va. Predicts that the southwestern Virginia deposits will become an important source of pyrites for acid manufacture.

5. Keith, Arthur, 1903, U. S. Geol. Survey Geol. Atlas, Cranberry [N. C.] folio (no. 90), p. 8.

Deposits of pyrite and chalcopyrite in hornblende gneiss at Elk Knob have been prospected for copper.

6. Olcott, E. E., 1875, The Ore Knob copper mine and reduction works, Ashe County, N. C.: Am. Inst. Min. Eng. Trans., vol. 3., pp. 391-397.

Ore Knob deposit has been explored by shafts and drifts over a distance of half a mile. Gossan is 40 to 68 ft deep, and underlain by black, secondary copper ore; the primary sulfide ore, consisting of chalcopyrite, pyrrhotite, pyrite, magnetite, and silicates, lies below. The extent of the workings in secondary and primary ores is shown in a longitudinal section. The Hunt and Douglas method of leaching copper from the ore by iron chloride solution is described.

7. Pratt, J. H., and Berry, H. M., 1919, The mining industry in North Carolina during 1913-17, inclusive: North Carolina Geol. and Econ. Survey, Econ. Paper 49, p. 88.

Notes that Oliver pyrite mine, 6 miles from Dallas, Gaston County, is principal mine in State. Pyrite deposit reported near Otto, Macon County.

No. Dakota

Lignite pyrites - 1

1. Magnusson, Adelynn, 1950, Sulfur in North Dakota lignite: North Dakota Acad. Sci. Proc., vol. 3 (1949), pp. 18-21.

Sulfur occurs in N. Dak. lignites as iron pyrites, organic compound, and as iron and calcium sulfates; the sulfates are practically absent in freshly mined coal. The sulfur content of N. Dak. lignites is low, the average from 546 mines being 0.65 percent; organic sulfur usually composes 50 percent or more of the total sulfur.

Ohio

Coal pyrites - 1; P 10, 14

1. Tucker, W. M., 1919, Pyrite deposits in Ohio coal: Econ. Geology, vol. 14, pp. 198-219.

Pyrite balls in coal are as much as 2 ft in diameter, lenses average 1 ft in diameter and 2 in. in thickness, continuous layers of pyrite average 2 in. in thickness. Sulfur content of pure pyrite samples ranges from 23 to 51.2 percent. The lower coals of the State contain no commercial pyrite. The chief productive coal beds are the Middle

Middle Kittanning No. 6 and the Pittsburg No. 8, with smaller areas in the Pomeroy No. 8A, the upper Freeport No. 7, and the Lower Kittanning No. 5 coals. Total possible production is 250,000 tons yearly. A table lists names of mines, location, percent pyrite by weight, and percent of sulfur; three areal maps show coal beds and pyrite areas.

Oregon

Almeda mine, Josephine County - 4
Clover Creek mine, Baker County - 1
Cowboy mine, Jackson County - 3, 5
Queen of Bronze mine, Jackson County - 5
Silver Peak district, Douglas County - 2, 4
Squaw Creek district, Jackson County - 2, 4

1. Gilluly, James, 1937, Geology and mineral resources of the Baker quadrangle, Oreg.: U. S. Geol. Survey Bull. 879, pp. 107-109.

Pyrite, chalcopyrite, and barite occur in mineralized zone in greenstone at Clover Creek mine.

2. Oregon Dept. Geology and Mineral Industries, 1940, Oregon Metal Mines Handbook, Bull. 14-C, vol. 1, pp. 110-116.

Quotes from Shenon's discussion of the Squaw Creek and Silver Peak districts.

3. Shenon, P. J., 1932, A massive sulphide deposit of hydrothermal origin in serpentine: Econ. Geology, vol. 27, pp. 597-613.

Describes the geology and ore deposits of the massive sulfide deposit at the Cowboy mine, Josephine County, Oreg. The deposit consists of a series of lenticular ore bodies in serpentine along a fault zone near a greenstone contact; the series of ore lenses have a maximum length of 170 ft and are up to 7-8 ft in width. Abundant sulfides are pyrrhotite, chalcopyrite, sphalerite, cobalite and cubanite; sparse gangue minerals are serpentine, calcite, quartz, and epidote. Total production from 1903 to 1930 is estimated at 5,000 tons; very little reserve ore was blocked out. The ore shoot has been developed to a depth of 170 ft down the dip, intersecting six major lenses; proportions of the sulfides vary greatly. Shipping ore is said to average about 14 percent Cu, $1 per ton in Au, considerable Zn, and a little Ag.

4. Shenon, P. J., 1933, Copper deposits in the Squaw Creek and Silver Peak districts and at the Almeda Mine, southwestern Oregon with notes on the Pennell & Farmer and Banfield prospects: U. S. Geol. Survey Circ. 2, 35 pp.

The deposits of the Squaw Creek district, Jackson County, are replacement bodies in schist as much as 40 ft in width and containing variable amounts of quartz and sulfides, chiefly pyrite and chalcopyrite. Pyrite is the most abundant sulfide. At the deposits of the Silver Peak district, Douglas County, sulfides occur as massive, tabular, and disseminated bodies in schist. Chief sulfides are pyrite, sphalerite, chalcopyrite and bornite. A total of 3,294 tons of ore was shipped from 1922 to 1930; production figures and metal content of ore is given. The Almeda mine, 4 miles from Galice, lies in a zone of silicification within porphyritic dacite and argillite. Pyrite is by far the most abundant sulfide and is concentrated as massive bodies in the richer ore shoots.

5. Shenon, P. J., 1933, Geology and ore deposits of the Takilma-Waldo district, Oregon: U. S. Geol. Survey Bull. 846-B, pp. 141-192.

The two deposits that carry appreciable pyrrhotite are the Cowboy mine and the Queen of Bronze mine. The ore at the Queen of Bronze mine occurs as disconnected irregular bodies ranging in size from stringers to bodies of 10,000 tons; the ore is in greenstone near contacts with serpentine. Unsorted stope samples assay 4-7 percent Cu and 0.04-0.1 oz of Au per ton. Primary sulfides are pyrite and chalcopyrite with minor pyrrhotite and sphalerite; largest ore shoot is 70 ft in vertical extent. Total production is estimated at 35,000 tons. The Cowboy mine is also described.

Pennsylvania

Coal pyrites - 6, 10; P 10, 14
Boyertown deposits, Berks County - 12
Cornwall mine, Lebanon County - 1, 3, 12
Dillsburg mines, York County - 2, 4, 9, 12
Friedensville mine, Lehigh County - 7, 8; P 10
Gap mine, Lancaster County - 5
Jones mine, Berks County - 11, 12
South Mountain mine, Lehigh County - 7, 8,
Warwick (French Creek) mine, Chester County - 11, 12

1. Callahan, W. H., and Newhouse, W. H., 1929, A study of the magnetite ore body at Cornwall, Pa.: Econ. Geology, vol. 24, pp. 403-411.

The magnetite ore body occurs in metamorphosed Paleozoic limestones along the contact with a body of Triassic diabase. The ore deposit is believed to be genetically related to the diabase. Specularite, pyrite, marcasite, and chalcopyrite occur with magnetite; the relative abundance of these minerals is not stated.

2. Harder, E. C., 1910, Structure and origin of the magnetite deposits near Dillsburg, York County, Pa.: Econ. Geology, vol. 5, pp. 599-622.

Magnetite deposits occur in Triassic limestone conglomerate that has been metamorphosed by large bodies of diabase. Pyrite is associated with the magnetite ore. Geology and deposits are described.

3. Hickok, W. O., 1933, The iron ore deposits at Cornwall, Pa.: Econ. Geology, vol. 28, pp. 193-225.

A magnetite deposit occurs in Cambrian limestone and dolomite metamorphased by a thick Triassic diabase dike. Ore was formed by emanations from the diabase. Each of the two ore bodies is several thousand feet long. Geology, mineralogy, and origin of the deposit are discussed in detail. Pyrite is abundant in the ore, forming 10 to 15 percent of ore in places, but averaging from 1 to 2 percent; pyrite is separated during flotation, and sulfur, cobalt, and iron are recovered. Chalcopyrite is common, averaging about 0.25 percent of the ore; it is also recovered. Total production of iron ore until 1930 is estimated at 35,000,000 tons; current annual production is over 1,000,000 tons.

4. Hotz, P. E., 1950, Diamond-drill exploration of the Dillsburg magnetite deposits, York County, Pa.: U. S. Geol. Survey Bull. 969-A, 27 pp.

The results of geologic studies made in cooperation with a Bureau of Mines drilling project are presented. Magnetite deposits are replacements of lenticular limestone beds in a large plate of Triassic sediments sandwiched between two diabase sheets. Iron-rich fluids are believed to have been derived from the lower diabase sheet. Deposit and ores are similar to those of Cornwall, Pa. Pyrite is the most abundant metallic gangue mineral accompanying the magnetite.

5. Kemp, J. F., 1894, The nickel mine at Lancaster Gap, Pa., and the pyrrhotite deposits at Anthonys Nose, on the Hudson: Am. Inst. Min. and Eng. Trans., vol. 24, pp. 620-633.

A brief description of the Gap nickel deposit is given, and its origin is extensively discussed. Nickeliferous pyrrhotite with chalcopyrite occurs on the borders of the eastern part of a body of amphibolite that is several thousand feet long. The sulfides are believed to have been segregated from the original magma. The Philips pyrrhotite deposit at Anthony's Nose is briefly mentioned; it is a pyrrhotite lens in gneiss, and has no similarities to the Gap deposit. Philips mine was worked to depth of 300 or 400 ft and for several hundred feet along the strike. It was operated for 10 or 15 yrs and ore burned for acid in a nearby plant; Sicilian sulfur is now used here for acid manufacture.

6. Leighton, Henry, 1922, Pyrite from bituminous coal mines in Pennsylvania: Pennsylvania Topog. and Geol. Survey Bull. 48, 19 pp.

Pyrite and marcasite occur in the coals of Pennsylvania as lenses, nodules, balls, plates, and thin scales. Pyrites content varies considerably in the different coal beds, but is generally higher in the older beds. Pyrite is currently recovered at but one mine in the State, near Stoneboro, Mercer County, where 4 to 5 tons are recovered daily from 600 tons of coal. Estimates that about 200,000 tons of pyrites could be recovered annually from bituminous coals of Pennsylvania. The most promising fields for pyrite recovery appear to be near the northern, northeastern, and eastern margins of the bituminous basin or in the peripheral subbasins. Lists pyrite available from 17 districts and gives map of localities.

7. Miller, B. L., 1924, Lead and zinc ores of Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. M5, 91 pp.

Pyrite occurs in considerable amounts with sphalerite at the Friedensville mine. Nearby limonite deposits are underlain by pyrite.

8. Miller, B. L., and others, 1941, Lehigh County, Pa.: Geology and geography: Pennsylvania Geol. Survey, 4th ser., Bull. C39, 492 pp.

Pyrite has been found at depth at a number of limonite deposits in the county; largest deposit of this type known is in Cambrian quartzite, on South Mountain. Pyrite occurs in large quantities in the Friedensville zinc mines.

9. Neumann, G. L., 1947, Investigation of the Dillsburg magnetite deposits, York County, Pa.: U. S. Bur. Mines Rept. Inv. 4145, 13 pp.

About 1,500,000 tons of magnetite ore was shipped from this area between 1855 and 1915. The ore is chiefly magnetite with variable amounts of pyrite and chalcopyrite; it is similar to ore of the Cornwall magnetite deposit, from which cobalt-bearing pyrite and chalcopyrite are recovered. The deposit is in metamorphosed Triassic rocks adjacent to diabase. The Bureau of Mines made a magnetic survey and drilled nine holes in 1945-46. No sulfur assays are given.

10. Selvig, W. A., and Seaman, Henry, 1929, Sulfur forms and ash-forming minerals in Pittsburgh coal: Carnegie Inst. Technology Cooperative Bull. 43, 21 pp.

The Pittsburgh coal bed was sampled at one mine by a series of samples across the bed in four different sections of the mine. Proximate and ultimate analyses were made of the samples. Total sulfur content of the entire bed ranged from 1.16 to 2.19 percent. Organic sulfur generally exceeded pyritic sulfur, and was highest in the top and bottom portions of the beds.

11. Smith, L. L., 1931, Magnetite deposits of French Creek, Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. M-14, 52 pp.

The ore is magnetite associated with large amounts of pyrite and minor chalcopyrite. Pyrite is third in order of abundance among the gangue minerals and constitutes a large percentage of the ore. In 1928 the mine was closed because the ore was exhausted.

12. Spencer, A. C., 1908, Magnetite deposits of the Cornwall type in Pennsylvania: U. S. Geol. Survey, Bull. 359, 102 pp.

Magnetite deposits occur along the edges of the belt of Triassic rocks in southeastern Pennsylvania over a distance of about 100 miles. Most of the deposits are in metamorphosed limestone or limy rocks adjacent to diabase intrusions. Iron-bearing solutions may have been derived from the diabase. The ores are mainly magnetite, with some specular hematite at several localities. Pyrite is rather abundant, and chalcopyrite is present in some deposits. The principal deposit is the one at Cornwall in the center of the belt; more than 21,000,000 tons of iron ore has been produced here. The other deposits of importance are those near Boyertown to the east, and near Dillsburg to the west.

So. Carolina

Haile mine, Lancaster County - 3, 4, 5; P 10
Nanny Mountain prospect, York County - 1; P 10
Ross prospect, York County - 2; P 10

1. Graton, L. C., 1906, Reconnaissance of some gold and tin deposits of the southern Appalachians: U. S. Geol. Survey Bull. 293, pp. 115-116.

Some of the limonite deposits in the Kings Mountain area of North Carolina and South Carolina were found to be pyritic in depth. Pyrrhotite has been found by drilling at Nannies Mountain, South Carolina. Pyrite was mined a few miles north of Kings Mountain, but operations have been stopped. Sulfuric acid was manufactured at Blacksburg, S. C., from pyritic gold ore from local mines.

2. Keith, Arthur, 1931, U. S. Geol. Survey Geol. Atlas, Gaffney-Kings Mountain, S. C.-N. C., folio (no. 222), p 13.

Pyrite has been mined in Lincolton quadrangle to the north, and burned for acid manufacture at Blacksburg. Two deposits have been prospected in South Carolina; several feet of pyritized quartz-sericite schist occurs at the Ross property, and pyrite occurs in vein quartz in the other deposit.

3. Pardee, J. T., and Park, C. F., Jr., 1948, Gold deposits of the southern Piedmont: U. S. Geol. Survey Prof. Paper 213, pp. 112-117.

Includes a detailed account and geologic maps of the Haile gold-pyrite deposit, Lancaster County, S. C.

4. Schrader, F. C., 1922, Pyrite at the Haile mine, Kershaw, S. C., with a note on the pyritization at the Brewer mine, near Jefferson: U. S. Geol. Survey Bull. 725-F, pp. 331-345.

The Haile mine has been the most productive gold mine in the southeast; its production from 1830 to 1908 was about $3,500,000 in gold. Deposit was worked for pyrite from summer of 1915 to January 1919. Country rock is quartz-sericite schistose tuff, with silicified and pyritized zones; the mineralized area is partly covered by younger sediments of Cretaceous age. Gold ore is highly siliceous and pyritic. Most of the pyrite ore consists of very fine-grained, disseminated pyrite, and has an average sulfur content of 22.5 percent. About 12 percent of the ore is judged to consist of lump or massive ore averaging about 42 percent sulfur. Pyrite reserves in three mineralized zones are estimated to be equivalent to 600,000 tons of concentrates and ore. At the Brewer gold mine, 10 miles to the northeast, the pyrite content is too low to be minable.

5. Watkins, J. H., 1918, Pyrite mining at Kershaw, S. C.: Eng. and Min. Jour., vol. 106, pp. 517-521.

Extensive zones of pyritized schists occur at the old Haile gold mine. Gold is most abundant in silicified zones; pyrite is abundant in sericitized schists. Gold mining ceased in 1908; pyrite mining was started in 1915, and about 8,500 tons of massive ore mined by June 1917. Present operation is mining pyritized schist containing about 25 percent pyrite. Four tons of ore yield one ton of pyrite concentrate having 47 percent sulfur.

So. Dakota

Hardin mine, Lawrence County - 1
Whizzers mine, Lawrence County - 2; P 10

1. Irving, J. D., and Emmons, S. F., 1904, Economic resources of the northern Black Hills: U. S. Geol. Survey Prof. Paper 26, pt. 2, pp. 162-163.

Pyritic deposits of the Two Bit district near Deadwood are replacement deposits along vertical fractures in quartzite, shale, and porphyry. Shoots of considerable width are said to occur in the Hardin mine which is the only deposit of workable size. Pyrite is reported to carry low gold values.

2. Storms, W. H., 1905, A noted pyrite deposit: Min. and Sci. Press, vol. 91, pp. 290-291.

Gives a brief account of the Whizzers pyrite mine near Deadwood, S. Dak. Deposit consists of pyrite with small amounts of chalcopyrite and variable amounts of gold in hornblende schist. Vein has been opened for a length of over 600 ft; has a width of 45 ft in places. Pyrite was shipped to Deadwood and Delaware smelter for use in smelting siliceous ores.

Tennessee

Coal pyrites - 5; P 10, 14
Ducktown district, Polk County - 1, 2, 3, 4, 9; P 4, 7, 9, 10, 12, 13
East Fork mine, Sevier County - 8
Stoney Creek deposits, Carter County - 1, 2, 6, 7

1. Ashley, G. H., 1919, Outline introduction to the mineral resources of Tennessee: Tennessee Geol. Survey Bull. 2A, 65 pp.

A brief note on pyrite occurrences in the State is given. Pyrite has been mined at Stoney Creek, Carter County (12 miles northeast of Elizabethton); it is reported that 1,000 tons were mined here in one year. Large amounts occur in the Ducktown copper district, and in Moore, Cheatham, and Greene Counties. Pyrite is also found in the Chattanooga black shale.

2. Born, K. E., 1936, Summary of the mineral resources of Tennessee: Tennessee Div. Geology, 102 pp.

Gives a brief note on pyrite occurrences that is essentially the same as the information in Ashley's report.

3. Emmons, W. H., and Laney, F. B., 1926, Geology and ore deposits of the Ducktown mining district, Tennessee: U. S. Geol. Survey Prof. Paper 139, 114 pp.

Country rocks are mainly graywacke, arkose, and mica schist, and are closely folded and faulted.

Ore deposits are huge massive sulfide bodies of tabular to irregular foldlike shapes; they occur along faults and in strongly folded zones, and are as much as several hundred feet in width and several thousand feet in length. Pyrrhotite is the chief sulfide mineral, and is accompanied by variable amounts of pyrite, chalcopyrite, sphalerite, and magnetite, as well as a large suite of silicate minerals. Limonitic gossan originally capped the deposits; a layer of secondarily enriched chalcocite ores lay at the base of the gossan and above the primary sulfides. The mines are described in detail. The deposits were first worked in the 1840's for the rich secondary copper ores, and later worked for the primary copper ores and gossan iron ores. Total copper production to the end of 1922 was about 408,000,000 pounds; iron production to the close of iron mining in 1907 was about 15,000,000 tons. Methods of treating the ores and manufacture of sulfuric acid are described; acid capacity exceeds 1,000 tons a day.

4. Ffolliott, J. H., 1942, Exploration and development of Boyd mine: Am. Inst. Min. Met. Eng., Tech. Pub. 1493, 12 pp.

The Boyd ore body in the Ducktown district was explored by dip-needle survey and diamond drilling. Deposit is a narrow, leanly mineralized vein near the surface; at 850 ft below the surface it is a massive sulfide body with a width of more than 300 ft and length of more than 800 ft. The ore consists of pyrrhotite, pyrite, sphalerite, chalcopyrite, and magnetite. Development and mining methods are described.

5. Holbrook, E. A., and Nelson, W. A., 1919, The coal pyrite resources of Tennessee and tests on their availability: Tennessee Geol. Survey, Resources of Tennessee, vol. 9, no. 1, pp. 60-70.

Pyrite occurs as bands, nodules, and kidneys in some of the coal seams of the Cumberland Plateau. The mines in the Bon Air-Clifty district could probably produce at least 50 tons of pyrite daily, and mines on the Monterey branch of the Tennessee Central might yield 40 tons daily. Pyrite is being recovered by the Fentress Coal Co. in the latter district. Concentrating tests on crude coal pyrite samples indicate that a merchantable product can be made by coarse crushing and jigging.

6. Keith, Arthur, 1907, U. S. Geol. Survey Geol. Atlas, Roan Mountain [Tenn.-N. C.] folio (no. 151), p. 10.

Pyrite occurs in practically all the Cambrian quartzites, but is most abundant in the uppermost beds of the Erwin. It was mined at one time at Stoney Creek for use in acid manufacturing.

7. King, P. B., and others, 1944, Geology and manganese deposits of northeastern Tennessee: Tennessee Div. Geology Bull. 52, pp. 188-189.

In the Stoney Creek area, fine-grained pyrite occurs in silicified shale of the Erwin formation, in beds 4 ft thick beneath a thrust fault. About 1,000 tons of ore was mined at the Helenmode and Hatcher mines.

8. Stose, G. W., and Schrader, F. C., 1923, Manganese deposits of east Tennessee: U. S. Geol. Survey Bull. 737, pp. 102-105.

At the East Fork manganese mine, Sevier County, pyrite occurs in a manganese carbonate deposit along the vertical contact between dolomite and slate beds.

9. Taylor, J. H., 1918, Pyrite and pyrrhotite resources of Ducktown, Tenn.: Am. Inst. Min. Eng. Trans., vol. 59, pp. 88-92, 1918: <u>also</u> Am. Inst. Min. Eng. Bull. 134, pp. 529-533.

A brief summary of the cupriferous pyrrhotite deposits of the Ducktown district and current mining operations.

Texas

Riley Mountain prospect, Llano County - 1, 2

1. Paige, Sidney, 1911, Mineral resources of the Llano-Burnet region, Texas: U. S. Geol. Survey Bull. 450, pp. 54-55.

Includes a description by A. C. Spencer of the pyritic deposits along the east base of Riley Mountain. Arsenopyrite was found in a mass 15 ft wide and 25 ft long beneath gossan on the Roberts place; deposit is close to a fault between Paleozoic limestones and pre-Cambrian schists. Several miles to the north, limonite pseudomorphs after pyrite occur along a fault between cherty limestone and red sandstone.

2. Paige, Sidney, 1912, U. S. Geol. Survey Geol. Atlas, Llano-Burnet [Tex.] folio, (no. 183), 115 pp.

Brief mention of deposits of pyrite along the east base of Riley Mountain between Click and Packsaddle. A mass of arsenical pyrite south of Honey Creek in limestone near a fault is 15 ft wide and exposed for a length of 25 ft. One mile north of Honey Creek is a deposit in a crush-zone adjacent to a fault, in a filling of crushed, cherty limestone and sandstone.

Utah

Bingham district, Salt Lake County - 1, 3, 4, 6; P 10
Cactus mine, Beaver County - 2
Eagle Silver (Argent) mine, Tooele County - 9
East Tintic district, Utah County - 7, 8
Horn Silver mine, Beaver County - 2
Wah Wah mine, Beaver County - 5

1. Boutwell, J. M., 1905, Geology of Bingham mining district, Utah: U. S. Geol. Survey Prof. Paper 38, 413 pp.

Pyrite forms the bulk of large replacement ore bodies in limestone and is the most common sulfide in the district. It occurs in close association with chalcopyrite. Disseminated and lode ore deposits of the district are relatively low in pyrite content.

2. Butler, B. S., 1913, Geology and ore deposits of the San Francisco and adjacent districts, Utah: U. S. Geol. Survey Prof. Paper 80, 207 pp.

Deposits occur in quartz monzonite, in sediments, and in lava flows. Chief sulfides of Cactus ore zone are pyrite and chalcopyrite. Chief sulfides in OK ore zone are pyrite, chalcopyrite, and molybdenite; pyrite is not abundant. The Horn Silver deposit lies in lava and the principal sulfides are galena, pyrite, and sphalerite.

3. Head, R. E., and others, 1935, Detailed statistical microscopic analyses of ore and mill products of the Utah Copper Co.: U. S. Bur. Mines Rept. Inv. 3288, 93 pp.

Presents results of microscopic analysis of the composite mill feed, concentrate, and tailings from the Magna and Arthur mills of the Utah Copper Co. for 1 month in 1929. Pyrite content was determined as follows:

Magna mill feed	2.150 percent pyrite
Arthur mill feed	2.036 percent pyrite

4. Hunt, R. N., 1924, The ores in limestone at Bingham, Utah: Am. Inst. Min. Met. Eng. Trans., vol. 70, pp. 856-883.

Copper and lead-zinc deposits occur in limestone beds in the quartzite-limestone series surrounding the monzonite porphyry which contains the huge disseminated ore body of the Utah Copper Co. Pyrite is an abundant constituent of the copper deposits in limestone. The Highland Boy, Yampa, Boston Consolidated, and other mines have yielded large tonnages of low-grade pyritic copper ores.

5. Jones, R. L., and Dunham, W. C., 1946, Examination of the Wah Wah lead-zinc mine, Beaver County, Utah: U. S. Bur. Mines Rept. Inv. 3853, 14 pp.

Ore bodies are replacement deposits in limestone and shale. Pyrite is the principal sulfide in the primary ore, and is accompanied by small amounts of galena, sphalerite, and chalcopyrite. The upper parts of the deposits are oxidized. Bureau of Mines unwatered the mine, extended some workings and did some drilling.

6. Jones, R. L., and Wilson, S. R., 1949, Diamond drilling at the Boston Consolidated Copper mine, Salt Lake County, Utah: U. S. Bur. Mines Rept. Inv. 4579, 21 pp.

A cupriferous pyrite deposit in limestone was explored by 36 underground drill holes by Bureau of Mines. A large mass of barren pyrite surrounds the ore zone. Pyrite distribution is noted in drill logs, but no sulfur assays are given.

7. Lindgren, Waldemar, and Loughlin, G. F., 1919, Geology and ore deposits of the Tintic mining district, Utah: U. S. Geol. Survey Prof. Paper 107, 282 pp.

Pyrite is the most abundant mineral in the lead-copper veins in the igneous rocks, and also occurs in abundance with quartz in the wall rocks. Pyrite is less important in the lead, copper, gold, and silver deposits in sedimentary rocks.

8. Lovering, T. S., 1949, Rock alteration as a guide to ore--East Tintic district, Utah: Econ. Geology Pub. Co., Mon. 1, 64 pp.

Discusses the stratigraphy and alteration of the district with brief notes on the structure and ore deposits. Country rocks are quartzite and carbonate sediments overlain by volcanics, all of which are intruded by quartz monzonite, latites, and pebble dikes. Pb - Zn - Ag replacement deposits are in calcareous sediments and pyritic Cu - Au veins are in quartzite. The stages of alteration were dolomitization of limestone; argillization of wall rocks; deposition of jasperoid, barite, pyrite, quartz, and calcite; sericitization adjacent to ore bodies; and the introduction of sulfides. In the jasperoid-stage pyrite was concentrated in the volcanics above mineralized fissures; pyritic halos occur in latite overlying jasperoid.

9. Young, W. A., 1950, Investigation of Eagle Silver lead-zinc mine, Tooele County, Utah: U. S. Bur. Mines Rept. Inv. 4680, 11 pp.

Lead-zinc deposits at Eagle Silver or Argent mine are in breccia zone in interbedded quartzite and limestone. The deposits were oxidized in the upper levels; abundant iron sulfides occur below. Bureau of Mines drilled nine holes from underground workings.

Vermont

Elizabeth mine, Orange County - 1, 2, 3, 4, 6, 7, 8, 9, 10, 11; P 10, 12, 13
Ely (Copperfield) mine, Orange County - 3, 5, 6, 9, 11; P 4, 9, 10, 12, 13
Eureka-Union (Pike Hill) mines, Orange County - 3, 6, 9, 11; P 10, 12, 13

1. Anderson, C. S., 1931, Mining and milling in the Vermont copper district: Eng. and Min. Jour., vol. 131, pp. 208-210.

Principally an account of the mining and milling methods at the Elizabeth copper mine during its period of operation from April 1929 to June 1930.

2. Benson, C. B., Wangaard, J. C., and Johnson, H. A., 1950, Elizabeth mine reorganized for efficient production: Min. Cong. Jour., vol. 36, no. 7, pp. 18-23.

Describes recent changes in mining and milling methods at the Elizabeth copper mine, Vt., that have resulted in increasing production from 450 to 750 tons of ore daily. The pyrrhotite content of the mill feed varies from 25 to 75 percent and averages 35 percent.

3. Buerger, N. W., 1935, The copper ores of Orange County, Vt.: Econ. Geology, vol. 30, pp. 434-443.

Describes the sulfide and gangue minerals of the copper ores of the Orange County, Vt., district. Pyrrhotite is the principal sulfide and is widely associated with chalcopyrite; cubanite, valleriite, and sphalerite occur in minor amounts, while pyrite and galena are rare.

4. Fay, A. H., 1909, The Vermont Copper Company: Eng. and Min. Jour., vol. 88, pp. 364-365.

Brief sketch of the ore deposit near South Strafford, previous and current mining operations, and smelting practice.

5. Hermance, H. P., Neumann, G. L., and Mosier, McHenry, 1949, Investigation of Ely Mine copper deposit, Orange County, Vt.: U. S. Bur. Mines Rept. Inv. 4395, 11 pp.

The Ely mine was worked at different periods from about 1820 to 1918. Production is estimated at more than 400,000 tons of ore averaging 3.3 percent copper. The deposit is an elongated lens in schist that has been followed for 3,400 ft down the plunge. Pyrrhotite is the chief sulfide mineral, and is accompanied by chalcopyrite, sphalerite, and pyrite. The Bureau of Mines sampled the mine dumps, made geophysical surveys, and drilled nine holes.

6. Jacobs, E. C., 1916, Copper mining in Vermont: Vermont State Geologist's Rept. 10, 1915-16, pp. 192-199.

A summary of the copper deposits of the State. The principal ones are the pyrrhotitic copper deposits of Orange County.

7. Jacobs, E. C., 1944, The Vermont Copper Company, Inc.: Vermont State Geologist's Rept. 24, 1943-44, pp. 1-13.

Summarizes information on geology of the Elizabeth copper mine and the area, and describes mining and milling methods used since reopening of mine in 1943.

8. Judson, J. N., 1909, The Vermont Copper Company: Eng. and Min. Jour., vol. 88, pp. 524-525.

Discussion of the article on the Vermont Copper Co. by Fay in the same journal (vol. 88, pp. 364-365).

9. Smyth, H. L., and Smith, P. S., 1904, The copper deposits of Orange County, Vt.: Eng. and Min. Jour., vol. 77, pp. 677-678.

A summary of the general geology of the region, and the structure and genesis of the cupriferous pyrrhotite deposits.

10. White, W. S., 1943, Geology of the Elizabeth copper mine, Vermont: Unpublished manuscript in open-files of U. S. Geol. Survey.

Report presents results of detailed geologic study of Elizabeth mine and vicinity, made while the mine was being explored and reopened in 1942-43. Ore bodies are shoots or long pods of massive sulfides, mostly pyrrhotite and chalcopyrite, that plunge gently to the north in the mineralized zone. Country rocks are quartz-mica schist, locally garnetiferous, and hornblende schist. The mine has produced about 400,000 tons of sulfide ore. Ore reserves are estimated at 708,000 tons of 2 percent copper ore. Maps and sections show details of geology and drill holes.

11. White, W. S., and Eric, J. H., 1944, Preliminary report: Geology of the Orange County copper district, Vermont: Unpublished manuscript in open-files of U. S. Geological Survey.

Describes results of geologic study of Orange County copper district, an area about 20 miles long and 5 miles wide. Principal rock types are calcareous schists and quartz-mica schists, with beds of needle amphibolite and coarse garnet schist locally. The massive sulfide bodies occur in faults and also in flexures or rolls in the cleavage. Pyrrhotite is the main sulfide mineral, and is accompanied by chalcopyrite and sphalerite; average copper content is 2 to 3 percent. Principal mines from south to north are Elizabeth, Ely, and Pike Hill or Eureka-Union mines; only Elizabeth is now accessible. Total district production has been between 50 and 60 million pounds of copper. All mines, except Elizabeth (see open-file report), are described in the text and maps.

Virginia

Coal pyrites - 3
Allah Copper mine, Louisa County - 2, 7
Anaconda mine, Buckingham County - 12
Arminius mine, Louisa County - 1, 2, 8, 11, 14; P 10, 13
Austin Run mine, Stafford County - 10; P 10
Austinville mine, Wythe County - PS 5 (1915)
Betty Baker mine (Gossan Lead), Carroll County - 9, 13, 14, 15; P 4, 7, 9, 10, 12, 13
Boyd Smith, Louisa County - 2, 8, 11, 14; P 10, 13
Cabin Branch mine, Prince William County - 10, 11, 14; P 10
Cranberry mine (Gossan Lead), Carroll County - 9, 13, 14, 15; P 4, 7, 9, 10, 12, 13
Julia mine, Louisa County - 2; P 10
Lightfoot mine, Buckingham County - 12
Monarat mine (Gossan Lead), Carroll County - 13, 14, 15; P 4, 7, 9, 10, 12, 13
New Canton mines, Buckingham County - 12; P 10
Old Dominion mine, Louisa County - 2
Piedmont (Lost Mountain) prospect, Madison County - P 10
Sulphur mine, Louisa County - 1, 2, 8, 11, 14; P 10, 13
Sutherland mine, Floyd County - 4
Toncrae-Howard mine, Floyd County - 5; P 12
Valzinco (Holladay) mine, Spotsylvania County - 2, 6

1. Adams, W. H., 1884, The pyrites deposits of Louisa County, Va.: Am. Inst. Min. Eng. Trans., vol. 12, pp. 527-535.

A general account of the recently opened pyrite mines of Louisa County; capacity of the Arminius and Sulphur mine is about 500 tons of ore daily. Predicts very favorable future for the district. Report has very little geologic information.

2. Cline, J. H., Watson, T. L., and Wright, F. J., 1921, A geologic map of the pyrite-gold belt in Louisa and Spotsylvania Counties, Va.: Virginia Geol. Survey.

A geologic map of the pyrite-gold belt of Louisa and Spotsylvania Cos., scale 1 in. to 1 mile; no text. Deposits are mainly in a belt of schists, 4 miles or more wide, between two granitic bodies. Eight pyrite deposits, 2 gossan iron deposits, 3 lead-zinc deposits, 32 gold deposits, and 1 manganese-iron deposit are shown on map.

3. Fish, F. H., and Addlestone, J. A., 1931, Sulfur forms in Virginia coals: Virginia Polytech. Inst. Bull., vol. 24, no. 15, (Eng. Exp. Sta. Ser., Bull. 7), 8 pp.

Organic sulfur is more abundant than pyrite sulfur in the coal samples investigated. In samples from 11 seams, organic sulfur made up 70.3 percent of the total sulfur; in 27 samples from the same mine, organic sulfur was 77.3 percent of the total.

4. Grosh, W. A., 1948, Investigation of the Sutherland copper prospect, Floyd County, Va.: U. S. Bur. Mines Rept. Inv. 4357, 2 pp.

The Sutherland deposit was prospected about 1850; there is no record that copper was ever produced from here. American Metal Co. drilled one hole here in 1939. Ore is pyrrhotite with minor chalcopyrite in mica schist. Bureau of Mines drilled 14 shallow holes in 1943 in search of secondary enriched copper zone.

5. Grosh, W. A., 1948, Investigation of the Toncrae-Howard copper deposits, Floyd County, Va.: U. S. Bur. Mines Rept. Inv. 4362, 4 pp.

The Toncrae deposit was worked on a small scale for iron (gossan ore) between 1800 and 1850, and for copper at different periods since then. Most of the copper production has been from enriched secondary ores. Primary ores are mainly pyrrhotite, with some pyrite, magnetite, chalcopyrite, and sphalerite in a zone more than 1,000 ft long in mica schist. The primary ores were explored with four drill holes by the American Metal Co. in 1938-39; the Bureau of Mines explored the enriched copper zone in 1943 by 29 shallow drill holes.

6. Grosh, W. A., 1949, Investigation of Valzinco lead-zinc mine, Spotsylvania County, Va.: U. S. Bur. Mines Rept. Inv. 4403, 7 pp.

Lead-zinc ore was produced from the Valzinco or Holladay mine from 1914 to 1918 and from 1942 to 1944. Deposit is about 10 miles northeast of Louisa County pyrite district. The deposit consists of two parallel veins in schist; minerals are chiefly sphalerite, galena, chalcopyrite, pyrite, and magnetite. The Bureau of Mines drilled nine holes in 1943, which were followed by five holes drilled by Panaminas, Inc., the operating company.

7. Grosh, W. A., 1949, Investigation of the Allah Cooper lead-zinc mine, Louisa County, Va.: U. S. Bur. Mines Rept. Inv. 4604, 6 pp.

The Allah Cooper deposit, several miles from the productive pyrite mines of Louisa County, was mined for lead and zinc prior to 1918. Minerals are galena, sphalerite, chalcopyrite, pyrite, and magnetite in quartz schist. The Bureau of Mines drilled one hole in 1943.

8. Hickman, R. C., 1947, Pyrites, Mineral, Louisa County, Va.: U. S. Bur. Mines Rept. Inv. 4116, 3 pp.

Pyrite ore was produced from the Arminius, Boyd Smith, and Sulphur mines during the period 1890 to 1922. Production was large, but total unknown. Pyrite is principal sulfide mineral and is accompanied by chalcopyrite, pyrrhotite, magnetite, sphalerite, and galena. Lenticular sulfide bodies occur in schist in a zone several miles long. Self-potential survey was made and one hole drilled in 1946. Low pyrite content in drill hole.

9. Kline, M. H., and Ballard, T. J., 1949, Investigation of the Great Gossan Lead, Carroll County, Va.: U. S. Bur. Mines Rept. Inv. 4532, 39 pp.

The Gossan Lead was mined for rich secondary copper cores in the 1850's and for gossan iron ore between 1890 and 1908. The General Chemical Division has been mining sulfide ore at the southern end of the Gossan Lead for about 40 yr for manufacture of H_2SO_4 at Pulaski, Va. plant; present production said to be 1,000 tons of ore daily. The ore is mainly pyrrhotite, with minor amounts of pyrite, chalcopyrite, and sphalerite. Large bodies of massive sulfides occur in schist in a zone about 17 miles long. This report gives results of drilling by the Virginia Iron, Coal & Coke Co. in 1927-28 (24 holes) and by the Bureau of Mines in 1947-48 (25 holes) on two tracts on northern part of Lead.

10. Lonsdale, J. T., 1927, Geology of the gold-pyrite belt of the northeastern Piedmont, Virginia: Virginia Geol. Survey Bull. 30, 110 pp.

Micaceous schists and gneisses are intruded by bodies of gabbro, diorite, granite, and pegmatite. The pyrite deposits are lenticular bodies in schist; minor amounts of pyrrhotite, chalcopyrite, galena, and sphalerite accompany the pyrite. The principal pyrite mine was the Cabin Branch mine which produced nearly 200,000 tons of pyrite from 1889 to 1920, when it was closed. The deposit was over 1,000 ft long and was mined to a depth of more than 1,000 ft. The Austin Run mine produced about 4,000 tons of pyrite between 1908 and 1920; it was opened to a depth of 650 ft.

11. Painter, R. K., 1905, Pyrite mining in Virginia: Eng. and Min. Jour., vol. 80, pp. 148-149, 433.

Describes mining and milling methods at pyrite mines near Mineral, Louisa County, and Dumfries, Prince William County.

12. Taber, Stephen, 1913, Geology of the gold belt in the James River basin, Virginia: Virginia Geol. Survey Bull. 7, 271 pp.

Describes the geology, petrology, and mineral deposits (principally gold) of the region. Pyritic-copper

deposits are found at several localities. Veins or lenses of pyrite and chalcopyrite occur in greenstone schist at the Lightfoot and Anaconda mines; small amounts of copper ore have been mined from workings less than 100 ft deep at these mines. Near New Canton is a mineralized zone about a mile long containing pyrite as small lenses and disseminations in quartz-sericite schist; chalcopyrite, pyrrhotite, and magnetite accompany pyrite. The principal mines in this zone are: Johnson, McKenna, Hudgins, and Margaret mines. They have been worked for iron (gossan ore) and copper; the Margaret was prospected for pyrite.

13. Van Mater, J. A., 1918, Pyrrhotite deposits of southwest Virginia: Eng. and Min. Jour., vol. 105, pp. 198-199.

Brief account of the Gossan Lead pyrrhotite deposits. Oxidized parts of the ore bodies were mined for copper and iron at an early date. The primary sulfide ore has been mined at the southwestern end of the belt since 1906 for H_2SO_4 manufacture.

14. Watson, T. L., 1907, Mineral resources of Virginia: The Virginia Jamestown Exposition Comm., Lynchburg, Va., 618 pp.

Describes pyrite deposits of Louisa and Prince Williams Counties that had produced more than half the total domestic output of pyrite (pp. 190-207). These deposits are cupriferous pyrite lenses in schist, and were worked at an early date for iron (gossan) and copper. Arminius mine was first worked for pyrite in 1865, and was developed to depth of 875 ft in 1907. Smith mine was opened about 1886, and was 300 ft deep in 1906. The Sulphur mines were first mined for pyrite in 1882, and were opened to depth of 720 ft by 1906. The Cabin Branch mine, Prince Williams County, was opened in 1889, and was developed by inclined shaft, 1,000 feet deep in 1907. The "Great Gossan Lead", Carroll County, has produced iron (pp. 475-476), copper (pp. 511-517), and is now being mined for pyrrhotite for H_2SO_4 manufacture (pp. 208-209).

15. Wright, R. J., and Raman, N. D., 1948, The Gossan Lead, Carroll County, Va.: Unpublished manuscript in open-files of U. S. Geol. Survey, 21 pp.

Gives results of geologic study made in 1943 of Gossan Lead, with particular attention to the secondary copper ores. Gossan Lead is a mineralized zone about 17 miles long, containing a series of elongated sulfide lenses, some of which are several miles in length. Pyrrhotite is the principal sulfide, and is accompanied by minor amounts of chalcopyrite and sphalerite; primary ore contains about 0.7 percent each of copper and zinc. Deposits are capped by limonitic gossan, as much as 50 or 60 ft thick; several feet of secondary chalcocite ore rests on the primary ore beneath the gossan. Deposits were first mined for rich secondary copper ores before Civil War; gossans were later worked for iron. Pyrrhotite is mined from the southern end of the Gossen Lead for H_2SO_4 manufacture. Reserves of secondary copper ores are unimportant.

Washington

Belcher mine, Ferry County - 1
Big Iron mine, Stevens County - 1, 2, 5
Holden mine, Chelan County - 4
Lockwood mine, Snohomish County - 3, 5
Napoleon mine, Stevens County - 1

1. Bancroft, H., 1914, The ore deposits of northeastern Washington: U. S. Geol. Survey Bull. 550, 211 pp.

The Big Iron deposit and the Napoleon mine in the Orient district, and the Belcher mine in the Belcher district are possible sources of pyrite. The Big Iron deposit, 12 miles from Rockcut, is a zone of pyrite replacement in schists intruded by monzonite porphyry. No massive sulfides; pyrite is principal ore mineral with minor chalcopyrite in a mineralized zone 100 ft wide and several hundred feet long. The Napoleon mine, 6 miles north of Marcus, is a replacement deposit in amphibolite carrying pyrrhotite, pyrite, some magnetite, and sparse chalcopyrite; mineralized zone is 60 ft wide, 300 ft long and developed to depth of 250 ft. Partly replaced amphibolite is more common than solid masses of sulfides; average ore said to assay 33 percent Fe, 12 percent S, 30 percent Si, 0.3 percent Cu, 10 percent Ca, and 0.7 oz of Au per ton. At the Belcher mine replacement ore bodies in limestone or dolomite, 4-20 ft wide, are chiefly pyrite and magnetite with some pyrrhotite; pyrite is more abundant than magnetite.

2. Broughton, W. A., 1945, Some magnetite deposits of Stevens and Okanogan Counties, Wash.: Washington Div. Geology Rept. Inv. 14, pp. 7-12.

Big Iron magnetite deposit in northern Stevens County is an irregular, contact metamorphic deposit in quartzite and limestone. Principal minerals are pyrite, pyrrhotite, and magnetite; the ratio of sulfides to magnetite is about 60 to 40. Minor amounts of chalcopyrite and scheelite are also present. About 35,000 tons of hand-picked iron ore, averaging 56 percent iron, was shipped between 1925 and 1937. The amount of waste discarded was about equal to the shipped product. From results of a magnetic survey it is estimated that the equivalent of 100,000 tons of similar hand-picked ore may remain.

3. Carithers, L. W., and Guard, A. K., 1945, Geology and ore deposits of the Sultan Basin, Snohomish County, Wash.: Washington Dept. Cons. and Devel., Div. Mines and Geology Bull. 36, 90 pp.

Brief notes are included on geology and exploration of the Lockwood pyrite deposit. It was explored in 1934 and 1937 by 225 ft of development and 35 open cuts, which showed three tabular pyritic bodies ranging from several feet to over 75 ft in width. Pyrite is accompanied by some pyrrhotite, and much quartz and sericite. Assays show 0.05 to 0.20 oz of Au per ton and 0.40 to 0.90 oz of Ag per ton. The deposit has been considered as a source of Fe and S; reserve estimates range from 500,000 to 2,500,000 tons.

4. Huttl, J. B., 1938, Howe Sound's Holden mine nears production: Eng. and Min. Jour., vol. 139, pp. 32-35.

The deposit is an irregular lens in metamorphosed sediments intruded by acid and intermediate rocks. Sulfides are chalcopyrite and pyrrhotite, pyrite, sphalerite, and galena in varying proportions, with some Au; ore accompanied by considerable silicification.

Development has been carried out on five levels; daily production estimated at 1,000 tons.

5. Zapffe, Carl, 1949, A review, iron-bearing deposits in Washington, Oregon, and Idaho: Raw Materials Survey Rept. 5, 89 pp.

Describes the Lockwood Pyrite property, Snohomish County, Wash., pp. 37-41. The deposit is chiefly pyrrhotite with pyrite and marcasite in sheared sediments interbedded with volcanic rocks and intruded by granodiorite; sulfides occur in a shear zone 100 ft wide with quartz gangue. A tunnel 250 ft long intersects three sulfide bands; average width is 21.8 ft and total length of the zone is 1,935 ft. Sulfides are finely disseminated; in half the samples taken they exceed 50 percent,(56.5 percent sulfides and 43.5 percent waste, based on W. P. A. sampling. From 2,761,920 to 3,729,600 tons of ore are estimated. There has been no production. Tables with analyses and mineral composition of the deposit. The Big Iron magnetite mine, Stevens County, Wash. is described briefly. Sulfide content of the ore is high; abundant pyrites on dumps. Sulfur content of large bulk sample from pit wall was 14.53 percent.

West Virginia

Coal pyrites - 1

1. White, I. C., 1920, Geographic distribution of sulfur in West Virginia coal beds: Am. Inst. Min. Met. Eng. Trans., vol. 63, pp. 932-944.

The average sulfur content in different coal beds is shown in a table and on maps. There seems to be an increase in sulfur content from the oldest coal beds in the eastern part of the State (less than 1 percent sulfur) to the youngest beds in the western part of the State (as much as 8 or 9 percent sulfur).

Wisconsin

Lead-zinc district, Southwest Wisconsin - 2, 3, 4, 5; P 2, 10
Mountain deposit, Oconto County - 1

1. Bagg, R. M., 1913, The discovery of pyrrhotite in Wisconsin, with a discussion of its probable origin by magmatic differentiation: Econ. Geology, vol. 8, pp. 369-372.

The deposit is 2½ miles southeast of Mountain, Wis. The country rock is granite cut by a basic dike carrying a small body of massive pyrrhotite. Three analyses average 54.1 percent Fe and 43.8 percent S. The only exploration is a shaft 10 ft deep, and the ore here is 13 ft wide. The sulfide mass may increase in size at depth, as the dike is vertical and 41 ft in width.

2. Bastin, E. S., and others, 1939, Contributions to a knowledge of the lead and zinc deposits of the Mississippi Valley region: Geol. Soc. America, Special Paper 24, 156 pp.

A series of papers on the stratigraphy, structure, igenous rocks, paragenesis, and origin of the lead-zinc deposits in Missouri, Arkansas, Kentucky, Oklahoma, Kansas, Illinois, and Wisconsin. The Wisconsin-Illinois district is discussed on pages 25-28, 67-69, and 114-118.

3. Behre, C. H., Jr., Scott, E. R., and Banfield, A. F., 1937, The Wisconsin lead-zinc district, a preliminary paper: Econ. Geology, vol. 32, pp. 783-809.

The structural features of the ore deposits are described and discussed. The deposits are mostly near the flanks of basins, and are mainly fracture fillings and mineralized faults. Both pyrite and marcasite occur with sphalerite and galena. Pyrite is more common along the periphery of the veins, whereas marcasite is present in the central parts.

4. Grant, U. S., 1906, Lead and zinc deposits of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 14, 100 pp.

Brief notes on the iron sulfides which are intimately associated with galena and sphalerite, especially with the latter. Marcasite is much more common than pyrite.

5. Heyl, A. V., and others, in preparation, Geology and ore deposits of the Upper Mississippi Valley zinc-lead district: U. S. Geol. Survey Prof. Paper.

Iron content varies from amounts equal to that of zinc in disseminated ore bodies (averaging 1-10 percent Fe) to amounts several times that of zinc (averaging 15-30 percent Fe). Vein-type ore bodies generally carry 8-15 percent Fe. A chapter on pyrite production is included. Marcasite and pyrite have been mined independently or recovered as a by-product of lead and zinc production; where the iron content was high and the zinc content low, iron sulfide was mined as the primary product with zinc and lead as by-products. Until 1949 iron sulfide concentrates obtained at the Vinegar Hill mill was used in the manufacture of sulfuric acid. No figures are available for iron sulfide used in acid production from 1926 to 1945. From 1911 to 1915 most of the production came from the Wilkinson mine at Cuba City (53,010 short tons). The Washburn mine at Arthur and the Meekers Grove open cut have both produced; in 1938 the latter had an output of 29,007 short tons.

Wyoming

Hartville district, Platte County - 1, 2, 3
North Laramie Peak district, Albany County - 2, 4

1. Ball, S. H., 1907, The Hartville iron-ore range, Wyoming: U. S. Geol. Survey Bull. 315-D, pp. 190-205.

Pyrite occurs in some of the pre-Cambrian schists. Limonite deposits in McCanns Pass, Haystack Mountains, are regarded as gossans.

2. Fischer, R. P., and others, 1947, Map showing metallic mineral deposits of Wyoming, U. S. Geol. Survey, Missouri Basin Studies no. 17.

Index map of metallic mineral deposits and brief text, with small inset geologic index map. Pyrites deposits not shown, but some copper deposits shown, as in Laramie Peak district, have or may have associated pyrites.

3. Smith, W. S. T., 1903, U. S. Geol. Survey Geol. Atlas, Hartville, Wyo., folio (no. 91), p. 5.

Pyrrhotite and chalcopyrite occur in the copper deposits associated with the hematite deposits in schist.

4. Spencer, A. C., 1916, The Atlantic gold district and the North Laramie Mountains: U. S. Geol. Survey Bull. 626, 85 pp.

The mineral deposits of the North Laramie Peak district, Wyoming, are tabular bodies or thin lenses in schists more or less thoroughly impregnated with pyrite and pyrrhotite; they carry minor chalcopyrite. Deposits similar to these at Esterbrook occur in the Hartville district in eastern Wyoming. Small amount of exploration done; no production.

Alaska

Beatson mine, Latouche Island - 1, 5
Ellamar mine, Prince William Sound - 3, 5
Horseshoe Bay deposit, Latouche Island - 5
Khayyam mine, Prince of Wales Island - 4, 7
Kupreanof Island prospect, Wrangell district - 2
Rua Cove deposit, Knight Island - 5, 6
Stumble-On mine, Prince of Wales Island - 4, 7
Zarembo Island prospect, Wrangell district - 2

1. Bateman, A. M., 1924, Geology of the Beatson Copper mine, Alaska: Econ. Geology, vol. 19, pp. 338-368.

Next to Kennecott, the Beatson mine has been the most productive copper mine in Alaska. Chalcopyrite, pyrite, and pyrrhotite, with minor amounts of sphalerite, galena, and cubanite are disseminated through graywacke, slate, flinty rock and chlorite schist in a broad zone adjoining the Beatson fault. Boundaries of this disseminated ore zone are determined by assays; sulfide content averages about 12 percent, of which chalcopyrite makes up about half. A body of massive iron sulfides with little copper lies along the fault. It has been traced for about 800 ft and ranges from 2 to 40 ft in width; this sulfide lens is left in the mine.

2. Buddington, A. F., 1923, Mineral deposits of the Wrangell district, in Mineral Resources of Alaska, 1921: U. S. Geol. Survey Bull. 739, pp. 69-70.

Brief notes on two pyrite bodies in chert and siliceous schist. The deposit on Zarembo Island near the head of St. Johns Harbor is $7\frac{1}{2}$ ft thick at one place and is exposed for a distance of 130 ft. A pyrite body on Kupreanof Island is about 4 ft wide and exposed for 50 ft.

3. Capps, S. R., and Johnson, B. L., 1915, The Ellamar district, Alaska: U. S. Geol. Survey. Bull. 605, 125 pp.

Copper deposits are the principal mineral deposits of the Ellamar district; greenstone, graywacke, and slate are the chief country rocks. Chalcopyrite, pyrite, and pyrrhotite occur most commonly in shear zones in greenstones. The deposit at the Ellamar mine, which has yielded nearly all the copper production of the district, is in sedimentary rocks. The Ellamar ore body consists of two distinct parts: a large lens of solid pyrite that forms the hanging wall and smaller, parallel lenses made up mostly of other sulfides. The Threeman and Landlock Bay copper mines are described as well as a number of prospects.

4. Fosse, E. L., 1946, Exploration of the copper-sulfur deposit, Khayyam and Stumble-On properties, Prince of Wales Island, Alaska: U. S. Bur. Mines Rept. Inv. 3942, 8 pp.

The deposits are lenses of massive copper and iron sulfides in hornblende gneiss and siliceous gneiss and schist. Principal minerals are chalcopyrite, pyrite, and pyrrhotite, with some sphalerite and magnetite, and small amounts of gold and silver. Exploration consisted of hand trenching and sampling of mine workings. Most of mining was done by Omar Mining Co. prior to 1908; production records are not available.

5. Moffit, F. H., and Fellows, R. E., 1950, Copper deposits of the Prince William Sound district, Alaska: U. S. Geol. Survey Bull. 963-B, pp. 47-80.

Copper deposits of Prince William Sound are mainly sulfide lenses and impregnations in sheared zones in greenstones, graywackes, and slates; pyrite, pyrrhotite, and chalcopyrite are the principal sulfide minerals. Copper production began in 1897 and ended in 1930. The Beatson mine and the Ellamar mine yielded more than 96 percent of the copper. Thirteen other companies were also productive, and there are numerous prospects in the area. Lenses of massive iron sulfides occur at some deposits, as at Horseshoe Bay, where two sulfide lenses have been explored; one lens has a developed length of 140 ft and a maximum thickness of 27 ft, and the other lens is at least 500 ft long, with a thickness ranging from 6 in. to 122 ft and averaging between 25 and 30 ft.

6. Stefansson, Karl, and Moxham, R. M., 1946, Copper Bullion claims--Rua Cove, Knight Island, Alaska: U. S. Geol. Survey Bull. 947-E, pp. 85-92.

The deposit appears to be a replacement of sheared greenstone along fault and fracture planes by pyrrhotite and chalcopyrite with minor sphalerite; pyrrhotite is the most abundant sulfide. Country rocks are quartz diorite and several kinds of greenstones and igneous rocks. Reserves averaging 1.25 percent Cu and about 40 percent Fe are 25,000 tons of measured and 1,125,000 tons of indicated ore.

7. Wright, F. E., and Wright, C. W., 1908, The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, 210 pp.

Principal types of ore deposits are sulfide lodes and lenses, carrying chalcopyrite and iron sulfides in slates and greenstones; and contact metamorphic deposits, made up of chalcopyrite, iron sulfides, magnetite, and silicate minerals, in metamorphosed limestone. Gold occurs in some of these deposits and also in quartz veins; some lead, zinc, and silver deposits occur. Deposits at the head of McKenzie Inlet, Prince of Wales Island, consist of sulfide masses and heavily mineralized schist; country rocks are dioritic intrusives and belts of schist and gneiss. At the Khayyam mine the ore bodies are four irregular lenses 6 to 20 ft in width; the main ore zone has been traced for 500 ft in length and is about 50 ft wide. Ore minerals are chiefly pyrite with disseminated chalcopyrite and minor pyrrhotite, sphalerite, and magnetite. Similar deposits at the nearby Mammoth and Lake View claims contain about 40 percent sulfur.

NAMES AND LOCATIONS, ON MAP, OF SULFUR AND PYRITES DEPOSITS

NATIVE SULFUR DEPOSITS

California

1. Supan deposits, Shasta County
2. Elgin mine, Colusa County
3. Sulphur Bank mine, Lake County
4. Auschwitz mine, Lake County
5. The Geysers, Sonoma County
6. Leviathan mine, Alpine County
7. Crater (Last Chance Range) mine, Inyo County
8. Coso Range deposits, Inyo County
9. Full Moon deposit, Imperial County
10. Coyote Mountain deposits, Imperial County

Colorado

1. Grand Junction deposit, Mesa County
2. Gunnison Fork mine, Delta County
3. Middle Fork and Trout Creek deposits, Mineral County

Florida

1. Floral City, Citrus County

Idaho

1. Soda Springs deposits, Caribou County

Louisiana

1. Starks dome, Calcasieu Parish
2. Sulphur dome, Calcasieu Parish
2. Jefferson Island dome, Iberia Parish
4. Belle Isle dome, St. Mary Parish
5. Dog Lake dome, Terrebonne Parish
6. Bay St. Elaine dome, Terrebonne Parish
7. Lake Pelto dome, Terrebonne Parish
8. Grande Ecaille dome, Plaquemines Parish
9. Venice dome, Plaquemines Parish
10. Garden Island Bay dome, Plaquemines Parish

Nevada

1. Humboldt (Rabbit Hole) mine, Humboldt County
2. Silver Peak (Blair) mine, Esmeralda County
3. Tognoni Springs deposit, Esmeralda or Nye County
4. Cuprite (Deep Gulch) mine, Esmeralda County

New Mexico

1. Jemez Sulphur Springs, Sandoval County

Oregon

1. Last Chance mine, Douglas County

Texas

1. Rustler Springs district, Culberson County
2. Palangana dome, Duval County
3. Orchard dome, Fort Bend County
4. Big Creek dome, Fort Bend County
5. Long Point dome, Fort Bend County
6. Nash dome, Fort Bend, and Brazoria Counties
7. Boling dome, Wharton County
8. Big Hill dome, Matagorda County
9. Clemens dome, Brazoria County
10. Hoskins Mound dome, Brazoria County
11. Bryan Heights dome, Brazoria County
12. Moss Bluff dome, Liberty County
13. Spindletop dome, Jefferson County

Utah

1. Cove Creek (Sulphurdale) mine, Beaver County
2. San Rafael Canyon, Emery County

Washington

1. Minnie prospect, Okanogan County
2. White River deposit, King County
3. Mt. Adams deposit, Yakima County

Wyoming

1. Sunlight Basin deposits, Park County
2. Sweetwater Creek deposits, Park County
3. Cody deposits, Park County
4. South Fork Shoshone River deposit, Park County
5. Thermopolis (Brutch) deposit, Hot Springs County
6. Afton deposit, Lincoln County

Alaska

1. Kanaga Island
2. MaKushin volcano, Unalaska Island
3. Akun Island
4. Mt. Hague, Pavlof Bay area
5. Stepovak Bay area

PYRITES DEPOSITS

Alabama

1. Stone Hill (Woods), Cleburne-Randolph Counties
2. Pyriton district, Clay County
3. McGee and Garrett prospects, Clay County

Arizona

1. United Verde mine, Yavapai County
2. Iron King mine, Yavapai County
3. Globe-Miami district, Gila County
4. Castle Dome mine, Gila County
5. Magma mine, Pinal County
6. Ray mine, Pinal County
7. Christmas mine, Gila County
8. Clifton-Morenci district, Greenlee County
9. San Manuel mine, Pinal County
10. Pima district (Sierrita Mtns.), Pinal County
11. Invincible prospect, Santa Cruz County

Arizona--Continued

12. Courtland-Gleeson district, Cochise County
13. Bisbee (Warren) district, Cochise County

Arkansas

1. Berryville (Newman) prospect, Carroll County
2. Hot Springs, Garland County
3. Caddo Gap, Montgomery County

California

1. Blue Ledge mine, Siskiyou County
2. Gray Eagle mine, Siskiyou County
3. Buzzard Hill mine, Siskiyou County
4. Afterthought mine, Shasta County
5. Bully Hill mine, Shasta County
6. Mammoth mine, Shasta County
7. Shasta King and Balaklala mines, Shasta County
8. Iron Mountain (Hornet) mine, Shasta County
9. Island Mountain mine, Trinity County
10. Big Bend mine, Butte County
11. Spenceville mine, Nevada County
12. Dairy Farm mine, Placer County
13. Redwood Copper Queen mine, Mendocino County
14. Newton mine, Amador County
15. Penn mine, Calaveras County
16. Quail Hill area, Calaveras County
17. Copperopolis district, Calaveras County
18. Leona Heights and Alma mines, Alameda County
19. American Eagle-Blue Moon mines, Mariposa County
20. Green Mountain mine, Mariposa County
21, Fresno Copper and Copper King mines, Fresno County
22. Vulcan deposit, San Bernardino County
23. Eagle Mountains mine, Riverside County
24. Friday mine, San Diego County

Colorado

1. Central City-Idaho Springs districts, Clear Creek and Gilpin Counties
2. Minnesota mine, Clear Creek County
3. Gilman (Red Cliff) district, Eagle County
4. Kokomo district, Summit County
5. Wellington mine, Summit County
6. Climax mine, Lake County
7. Leadville district, Lake County
8. Uncompahgre district, Ouray County
9. Camp Bird mine, Ouray County
10. Rico District, Dolores County
11. La Plata district, La Plata County

Georgia

1. Berrong and Ivey Mount prospects, Towns County
2. Number 20 mine, Fannin County
3. Chestatee mine, Lumpkin County
4. Standard and Swift (Blake) mines, Cherokee County
5. Dickerson and Smith prospects, Cherokee County
6. Canton (Rich) mine, Cherokee County
7. Bell-Star mine, Cherokee County
8. Magruder (Seminole) mine, Lincoln County
9. Marietta mine, Cobb County
10. Little Bob and Shirley mines, Paulding County
11. Rush-Banks prospect, Paulding County
12. Swift (McClarity) mine, Paulding County
13. Tallapoosa (Waldrop) mine, Haralson County
14. Villa Rica (Sulphur) mine, Douglas County
15. Jenny Stone prospect, Carroll County
16. Reeds Mountain mine, Carroll County
17. Cash prospect, Floyd County

Idaho

1. Coeur d'Alene district, Shoshone County
2. Red Ledge mine, Adams County
3. Blackbird district, Lemhi County

Illinois

1. Lead-zinc district, Jo Daviess County
2. Atkinson coal mine, Henry County
3. Soperville coal mine, Knox County
4. Coal mines, Vermilion County
5. Coal mines, Sangamon County
6. Coal mines, Christian County
7. Glen Carbon coal mines, Madison County

Indiana

1. Talleydale coal mine, Vigo County
2. Coal mines, Vigo County

Kansas

1. West Mineral coal mines, Cherokee County

Kentucky

1. Stearns coal mine, McCreary County

Maine

1. Katahdin deposit, Piscataquis County
2. Douglas, Blue Hill et al mines, Hancock County
3. Cape Rosier and Tapley mines, Hancock County

Massachusetts

1. Davis and Hawks mines, Franklin County

Michigan

1. Iron River district, Iron County

Minnesota

1. Long Lake region, Crow Wing County

Missouri

1. Marceline coal mine, Linn County
2. Vandalia coal mine, Audrain County
3. Lambert prospect, Miller County
4. Pioneer No. 2 prospect, Miller County
5. Copper mine, Maries County
6. Leslie mine, Franklin County
7. Duckworth and St. Clair mines, Franklin County
8. Kelsey and Rueppele mines, Franklin County
9. Cook prospect, Washington County
10. De Lore mine, Jefferson County

Missouri--Continued

11. Hobo mine, Crawford County
12. Cherry Valley mines, Crawford County
13. Flat Rock mine, Phelps County
14. Buckland mine, Phelps County
15. Moselle No. 10 mine, Phelps County
16. Fredericktown mines, Madison County
17. Starkey and Clay mines, Madison County
18. Hinote prospect, Wright County
19. Laswell mine, Howell County

Montana

1. Butte mines, Silver Bow County
2. Golden Curry (Elkhorn) mine, Jefferson County
3. Keystone mine, Broadwater County
4. Mouat nickel mine, Stillwater County

Nevada

1. Copper Canyon mine, Lander County
2. Mt. Hope mine, Eureka County
3. Yerington district, Lyon County
4. Ely mines, White Pine County
5. Pioche district, Lincoln County

New Hampshire

1. Milan mine, Coos County
2. Gardner Mountain district, Grafton County
3. Ore Hill (Warren) mine, Grafton County
4. Croydon and Neal mines, Sullivan County

New Jersey

1. Pochuck deposit, Sussex Company
2. Sulphur Hill (Andover) mine, Sussex County
3. Silver mine, Sussex County
4. Washington mine, Warren County
5. Hackelbarney and Cooper mines, Morris County

New Mexico

1. Pecos mine, San Miguel County
2. Magdalena District, Socorro County
3. Central (Hanover) district, Grant County

New York

1. Pyrites (High Falls) mine, St. Lawrence County
2. Cole mine, St. Lawrence County
3. Stella and Anna mines, St. Lawrence County
4. Edwards mine, St. Lawrence County
5. Balmat mine, St. Lawrence County
6. Clove mine, Orange County
7. Croft mine, Putnam County
8. Standish (Warwick) mine, Orange County
9. Phillips (Anthonys Nose) mine, Westchester County
10. Red-back mine, Orange County
11. Croton (Brewster or Theall) mine, Westchester County

North Carolina

1. Ore Knob mine, Ashe County
2. Elk Knob prospect, Watauga County
3. Big Ore Bank mine, Lincoln County
4. Crouse (Oliver or Pasour) mine, Gaston County
5. Fontana mine, Swain County
6. Cullowhee and Savannah mines, Jackson County
7. Otto (Macon or Cabes) prospect, Macon County

Ohio

1. Coal mines, Tuscarawas County
2. Coal mines, Harrison County
3. Coal mines, Jefferson County
4. Coal mines, Belmont County
5. Coal mines, Perry County

Oregon

1. Clover Creek mine, Baker County
2. Silver Peak district, Douglas County
3. Almeda mine, Josephine County
4. Squaw Creek district, Jackson County
5. Cowboy and Queen of Bronze mines, Jackson County

Pennsylvania

1. Stoneboro coal mines, Mercer County
2. Cascade coal mines, Clearfield County
3. Dillsburg mines, York County
4. Cornwall mine, Lebanon County
5. Gap mine, Lancaster County
6. Jones and Warwick (French Creek) mines, Berks and Chester Counties
7. Boyertown deposits, Berks County
8. Friedensville and South Mountain mines, Lehigh County

South Carolina

1. Ross prospect, York County
2. Nanny Mountain prospect, York County
3. Haile mine, Lancaster County

South Dakota

1. Hardin and Whizzers mines, Lawrence County

Tennessee

1. Coal mines, Overton County
2. Coal mines, Fentress County
3. Stoney Creek deposits, Carter County
4. East Fork mine, Sevier County
5. Ducktown district, Polk County

Texas

1. Riley Mountain prospect, Llano County

Utah

1. Bingham district, Salt Lake County
2. Eagle Silver (Argent) mine, Tooele County
3. East Tintic district, Utah County
4. Cactus and Horn Silver mines, Beaver County
5. Wah Wah mine, Beaver County

Vermont

1. Eureka-Union (Pike Hill) mines, Orange County
2. Ely (Copperfield) mine, Orange County
3. Elizabeth mine, Orange County

Virginia

1. Cabin Branch mine, Prince William County
2. Austin Run mine, Stafford County
3. Piedmont (Lost Mountain) prospect, Madison County
4. Valzinco (Holladay) mine, Spotsylvania County
5. Allah Cooper mine, Louisa County
6. Arminius, Boyd Smith, Sulphur, Julia, and Old Dominion mines, Louisa County
7. New Canton mines, Buckingham County
8. Lightfoot mine, Buckingham County
9. Anaconda mine, Buckingham County
10. Toncrae-Howard and Sutherland mines, Floyd County
11. Austinville mine, Wythe County
12. Betty Baker mine (Gossan Lead), Carroll County
13. Cranberry mine (Gossan Lead), Carroll County
14. Monarat mine (Gossan Lead), Carroll County

Washington

1. Big Iron and Napoleon mines, Stevens County
2. Belcher mine, Ferry County
3. Holden mine, Chelan County
4. Lockwood mine, Snohomish County

Wisconsin

1. Mountain prospect, Oconto County
2. Johns (Montfort) mine, Grant County
3. Lead-zinc mines, Iowa County
4. Lead-zinc mines, Grant County
5. Meekers Grove mine, Lafayette County
6. Wilkinson mine, Lafayette County
7. Other lead-zinc mines, Lafayette County

Wyoming

1. North Laramie Peak district, Albany County
2. Hartville district, Platte County

Alaska

1. Beatson mine and Horseshoe Bay deposit, Latouche Island
2. Rua Cove deposit, Knight Island
3. Ellamar mine, Prince William Sound
4. Kupreanof Island prospect
5. Zarembo Island prospect
6. Khayyam and Stumble-On mines, Prince of Wales Island

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